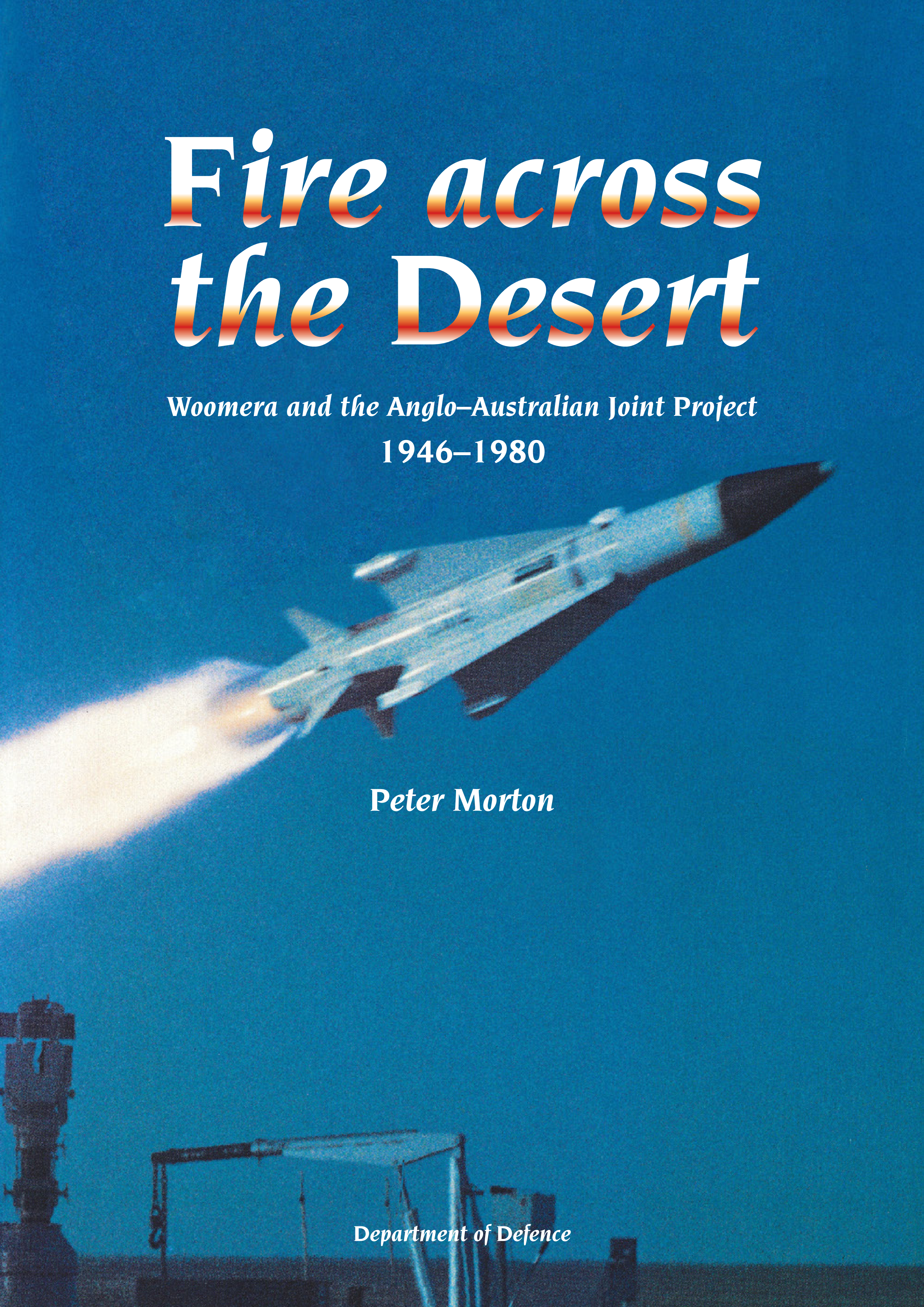

Fire across the Desert

Woomera and the Anglo–Australian Joint Project 1946–1980

Peter Morton

Department of Defence

In 1946 the Chifley government, joined in equal partnership with the British government of Clement Attlee, created a guided weapons experimental range and village at Woomera, and a sprawling research and development facility near the Adelaide suburb of Salisbury. This was the beginning of one of the most colourful, costly, and secretive episodes in post-war Australian history—the Anglo-Australian Joint Project.

Woomera and the Long Range Weapons Establishment were planned and built in the shadow of the German V-weapons, the deepening Cold War, discord with the United States, and the fearful certainty that warfare was about to be transformed by the advent of the nuclear-armed ballistic missile. At Woomera this anxious time saw the development and testing of many and various guided weapons and the Jindivik target aircraft. It also saw the instrumentation and growth of the biggest land range in the western world—a range which in its heyday reached right across the continent to the north-western coast. By this time the desert town of Woomera had expanded into a bustling, high- spirited community of six thousand. To Woomera there also came large liquid-fuelled research rockets like Black Knight and, in the late 1950s, vast facilities were constructed on the edge of Lake Hart for the testing of Britain's independent nuclear deterrent, Blue Streak.

Later, in the 1960s, Woomera played host to many bold space enterprises: the international consortium ELDO and its large three-stage satellite launcher rocket, EUROPA 1; the British Black Arrow and Australia's first and only home-built satellite, WRESAT. For a few years Australia had the opportunity and the resources to become an international space power but, for several reasons which are documented here, the chance was lost and the launcher facilities at Woomera were demolished. The joint project cost the partners several billion dollars in current terms, employed thousands at the Weapons Research Establishment and was responsible for developing much high technological expertise, especially in electronics and optics.

The product of more than three years' intensive research and writing sponsored by the Department of Defence, Fire across the Desert is the authoritative account of the history of Woomera up to 1980. Its various chapters deal not only with the glamorous, exciting and sometimes dangerous work of the Range but also with the social and domestic life of Woomera Village over the years. At the political level, the story provides some fascinating glimpses into how a national defence strategy is formulated and tells much about the relations between Australia and the 'Mother Country' in the post-war decades.

The author has had free access to all the surviving documents of the joint project in Australia. He was greatly supported by the formation of a history team at the Defence Research Centre Salisbury, and by the generous assistance of several specialist consultants and contributors. In Britain, the Ministry of Defence supplied the services of a researcher and allowed access to documents not available to the public.

Fire across the Desert tells the intimate story of an enterprise which for forty years has been kept under wraps. Written in a lively style and-fully illustrated from Defence archives, this is an important work about an intriguing period in Australia's history.

PETER MORTON was born in Leicester, England and educated at a local grammar school. His tertiary education was at the University of London and later he did postgraduate work at Sussex University. In 1972 he moved to Australia where he completed a doctorate at Flinders University and was subsequently Humanities Research Fellow.

Dr Morton has held several academic appointments in Britain and Australia and has alternated these posts with spells as a professional writer, technical journalist and writing consultant. He is the author of *The Vital Science: Biology and the Literary Imagination* 1860–1900 (Allen & Unwin, 1985) and has served as a book critic for the Adelaide Advertiser and the Australian. His articles and short fiction appear regularly in Quadrant and other magazines and scholarly journals.

At various times he has lived and worked in England, Italy and the United States, but his home is in Adelaide which he shares with his wife, who is an academic, and their young son.

Peter Morton is currently director of SCRIBO, an authorial and editorial consultancy which undertakes writing commissions for various corporate and government clients.

Cover photograph: A Seawolf short-range
naval weapon is fired from its six-barrel launcher
(courtesy of the Department of Defence).

Department of Defence

Fire across the Desert

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Peter Morton

Defence Science and Technology

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Foreword

Fire across the Desert is the history of one of the most significant defence undertakings Australia has embarked upon in peacetime.

For a third of a century the United Kingdom and Australia co-operated closely in building and operating a major missile testing range which at its peak reached far across our continent. This joint project began under the Chifley government and continued unbroken until 1980.

Australia's participation in the joint project was one of the key determinants in shaping our defence policy, and helped us come of age as a scientifically and technologically oriented nation.

The joint project indisputably accelerated the formation of a competent body of defence science staff in Australia and was a catalyst for the formation of today's Defence Science and Technology Organisation. Australia's approach to defence has, of necessity, changed fundamentally since the earlier post-war years, but much of the expertise gained on Woomera work has since flowed into current projects in keeping with our national defence priorities.

This history of the joint project was commissioned by the Department of Defence. Many departmental staff and retired officers generously contributed their time to its preparation and worked closely with the author, Peter Morton. The UK Ministry of Defence also gave close support.

I am confident that this work will be a valuable addition to the recorded history of Australian and British defence and space technology. And, most importantly, it recognises the major contribution made over a long period by a dedicated group of people in service of their country.

DAVID SIMMONS
Minister for Defence Science and Personnel

Contents

Part I: The Years of Establishment

Part II: The Years of Achievement

Part III: The Years of Decline

Preface

The proposal that a history should be written of the Anglo-Australian joint project in Australia—roughly speaking, the history of the Woomera Rocket Range and its support base at Salisbury, South Australia—antedates the end of the project itself. It was put forward by an officer of the Department of Defence as early as 1974. The vicissitudes of the history in the early stages of its gestation are well described by Mr Jim Frost in an appendix to this book. Let it suffice to say that over quite a number of years several false starts were made, most of them caused by the failure to realise that the task was of a magnitude which demanded the services of a professional writer with an academic background and special qualifications in scientific history.

Having accepted the commission in April 1983 I contracted to produce a manuscript in eighteen months, subject to certain reservations about the supply of documents and contributions from consultants. As I started work, a small team was formed within the Trials and Technology Support Division of the Advanced Engineering Laboratory at the Defence Research Centre Salisbury consisting of Jim Frost as task manager, Brian Polomka as research assistant and myself as writer. This team continued unchanged for some time but was later reduced to Jim Frost and myself.

When I first came to the task the plan of attack was that my chief role should be an editorial one: draft chapters were to be written by volunteer contributors (in many cases retired officers of the Department) and my job would be to edit them into consistency and weld them into a continuous narrative. With some sterling exceptions which I am pleased to note later, this scheme quickly proved unworkable for the simple reason that few contributions of usable quality were ever forthcoming. Eventually my contract period was extended and other funding made available to enable the team to research and write the bulk of the book from scratch.

From the beginning I had a clear idea of the kind of book I wanted to write, and I was happy to find that the other members of the team were in close agreement with me. No question but that the book had to be an authoritative history. The fact that records pertaining to the whole life of the joint project would be available exclusively to the team meant that we were breaking virgin ground; we would have been derelict not to make the most of an unparalleled opportunity. None of us, however, was attracted to the traditional idea of 'official history'; we particularly wanted to fight shy of the often deserved reputation of that genre for blandness and dullness. We felt that the story of Woomera deserved something better than that. The work done under the project was often exciting, sometimes spectacular and occasionally dangerous; and by its nature it attracted creative and sometimes eccentric minds. Then again, the conditions of life at Woomera, particularly in the early years, made it home to some strong and idiosyncratic personalities who gave it a very characteristic stamp.

But the book had to be a lot more than an exercise in nostalgia or colourful social history. The intent behind the project was a deadly serious one, especially in the first years when the very survival of the British Commonwealth was thought to depend on the speed with which the Range facilities were completed. The story had to cover a long and eventful episode in the history of the applied sciences in Australia, and had to deal with topics inherently difficult to popularise. Rocket engineering; the various physical sciences and technologies which have contributed to the success of ballistic and other guided weapons; the theory and practice of earth satellites: these are subjects which it is difficult to explain, let alone make palatable, to the lay reader. The book attempts to tread the tightrope between the scholarly and the popular. It is a statement of record. It is a technical history, and the social history of an unusual town. It tries indirectly to show how great national projects flow out of political ideology. It illuminates a facet of the long and involved relationship between the United Kingdom and Australia, and the story of the joint project is in one of its aspects the story of the progressive loosening of that bond. The reader must judge how far the finished product manages to weave together these diverse threads.

One weakness must be apparent to every reader. It is that the emphasis falls so heavily on the work of the joint project *in Australia* that, except perhaps for the first chapter and those devoted to the big rocket projects, scant justice is done to the British effort in Britain. As Brian Kervell, the Curator and Archivist of the RAE Museum once complained to me:

> The non-specialist reader might gain the impression that, in some mysterious way, things turned up in Australia for testing and almost ready for firing rather as in a Cargo Cult where dubious gifts from the gods arrive out of the blue to be utilised by bewildered islanders!

This is an acute comment and painfully accurate. I can only ask for the indulgence of my readers and beg them to allow for this inevitable bias throughout. The alternative was never possible, given the funding arrangements and the need to keep the history within one pair of covers.

The appearance of this book has been long delayed. At the outset we badly underestimated how much time and energy it would take to secure key documents and to have draft chapters cleared for publication. Although individual officers of the relevant departments were nearly always helpful when approached directly, the administrative procedures to which any large organisation must adhere are not easily negotiated by an author who to some extent is charting his own course, especially when he is working to a fixed-term contract. To give two examples: it took fourteen months to obtain permission for the author to inspect certain Australian Cabinet papers relating to the cancellation of Blue Streak; and it took the Ministry of Defence fifteen months to vet the chapter devoted to the Black Knight rocket. Though I never doubted for a minute the sincerity of the Department's wish to have the story of the joint project told in frank detail, the fact remains that the instinctive posture of defence bureaucracies the world over is one of secrecy, caution and the anodyne phrase. It was, after all, a former British Minister of Defence, Denis Healey, who said that dealing with his Ministry was like moving a grand piano while having his appendix out.

Given the nature of the subject of the history, it is necessary to say a few words about the question of censorship. When a history is commissioned from an independent author by a private firm or a government department, the question of censorship—or, to choose a more neutral word, vetting— must be squarely faced. Though even 'vetting' has a nasty ring to it, it can hardly be avoided in practice. Of course no professional historian is going to be told what to say, or will allow his narrative to be tinkered with by others to put a more favourable gloss on some event. On the other hand, it is unreasonable to expect the commissioning body to give its author carte blanche to say anything in print. There are legal constraints, especially in countries with strongly oppressive libel laws like Australia; there is the question of trade secrets; and in some cases, including obviously the present one, there is the issue of national security and sensitivity—state secrets.

But beyond these constraints lies a grey area. The historian and his employer may not agree over the interpretation of facts. Sometimes they may not even agree what the facts are. The author's judgments, evaluations and interpretations may be found to be wrong-headed, offensive or worse. His standards of good taste, the extent to which he is willing to invade people's personal privacy to round out an account, and his willingness to wash dirty linen in public, may differ so markedly from his employer's as to leave little common ground. A balance can be struck only by negotiation. As much agreement as possible, and especially about what is to be done if negotiations break down, should be reached before the work begins, and the terms should be written into the author's contract.

One condition of my employment was that the manuscript should be vetted by representatives of both the British and the Australian governments. But the grounds of that vetting were contractually limited to only two: possible defamation, and those bearing on national security and sensitivity. To this obligation both governments, with a little prodding, adhered. The reader can therefore be assured that where I have been compelled to make excisions to my text (they are very few) it has been on these limited grounds only. The corollary, of course, is that the commentary and evaluations are my own and I am responsible for them.

That this book ever achieved the form in which it now appears is due in part to the dedicated and voluntary assistance of many dozens of people who took the time to answer our endless and often ill-informed queries. We ask them to accept our heartfelt thanks. Due acknowledgment is paid elsewhere to our consultants and contributors, in a list which tries to be exhaustive. Our apologies if anyone has been inadvertently omitted, but there does come a point at which one can either keep perfect records or get the book written. To all those people who agreed to be interviewed, to those who have searched their memories and diaries, and to those who offered documents and written accounts, thank you.

NOTE ON THE UNITS OF MEASUREMENT AND CURRENCY

All measurements have been given in metric units except where the SI system permits other units, notably in measuring the heights of aircraft. Except in direct quotation, or where the original unit forms part of a name or title, the original imperial measurements have been silently converted to metric. Where precision is not required the converted quantity has been rounded-off. One ton has commonly been equated with 1000 kilograms or 1 tonne.

Where a sum of money is given in pounds, the context or a note should always make it clear whether pounds sterling or pounds Australian is intended. It is worth bearing in mind that for much of the joint project £1 sterling was worth about 25 shillings Australian, although any attempt to compare the purchasing power in one country of the other's money should be done with circumspection. There is no difficulty in converting amounts expressed in Australian pounds into the present dollars, for when the currency was decimalised on 14 February 1966 the dollar was fixed at the value of ten shillings.

Inflation is a problem for the historian of the 1950s and 1960s. The success with which governments have, as Voltaire said, 'reduced paper to its intrinsic value' particularly over the last decade or so means that the prices of twenty and thirty years ago appear so ludicrously small that they can easily give the wrong impression. That Australia put some five million pounds into the building of Woomera in the one year 1949-50 is not very impressive, until one calculates that this is equivalent to more than one hundred million dollars today. Occasionally, therefore, we have tried to give some impression of real values by expressing prices in terms of the present Australian dollar or the pound sterling. For this purpose we have used the most recent version of the Retail Price Index table published in the *Yearbook of Australia* and for Britain the General Index of Retail Prices issued by the Central Statistical Office, London. Such a conversion must be considered to be an approximate guide only.

A NOTE ON SOURCES

The joint project must be one of the most thoroughly documented episodes in Anglo-Australian history. Thanks to the administrative practice prevailing in both countries, a written record was made of every decision and every communication of any consequence. It is true that many files have been destroyed over the years; but very many more, though marked for burning long ago, have been preserved because no one has got round to carrying out the sentence. The result is that the historian quickly starts to suffer from a surfeit of memoranda. His most daunting problem is not to find material, but to make a choice of documents for closer attention. He cannot even glance at everything, let alone read it.

In Australia, most of the surviving documents of the joint project are in two large repositories: in the archives and central registry of the Defence Research Centre Salisbury, South Australia, and in the branches of Australian Archives in Canberra, Melbourne and Adelaide. Papers dealing expressly with the affairs of Woomera over the last thirty years are still at Woomera. Neatly filed and catalogued for the most part, they fill a room in the basement of the abandoned administrative building at the Technical Area, and they could form the basis of many more specialised studies. In the United Kingdom the main repositories are the Ministry of Defence archives and the Public Record Office Kew ('PRO' in footnotes). In aggregate the records of the joint project amount quite literally to many tonnes of paper and it would be absurd to pretend that the team has made detailed use of more than a fraction of them.

A word on the use of oral sources. An eminent scholar once rightly said that there is no such thing as 'oral history'; there is only oral evidence, 'history' being what historians make of all their evidence. We are convinced that it is foolish to make a shibboleth of oral evidence. Again and again during our work on this book we have been struck by the fallibility and the treachery of human memory, especially in the case of the elderly when they are looking back thirty or forty years. Although information obtained at interview has helped immeasurably in leavening the narrative with anecdote and vivid recollections, fortunately the documentation is so rich that only rarely did Jim Frost and myself have to rely on interviews exclusively over any factual matter. We are glad of this, for our respect for the value of personal reminiscence, especially on technical issues, dropped sharply as we went on.

The notes at the end of each chapter give references which are as full as possible at the time of publication. Much of the primary documentation on which this book rests, however, still bears a security classification; much of it anyway is too recent to come under the provisions of the 'thirty-year' rule which governs public release. Some was drawn from the internal files of government departments; some is to be found in the collections of personal papers already held in Australian Archives to which there is restricted access; some is in the form of audio-taped interviews given to the team in confidence or transcripts of them. The Shedden Papers, which are cited at various points, are currently held by the Archives and Historical Studies section of DOD but are being prepared for transfer to Australian Archives.

It is intended that as many as possible of the files, documents and audio- tapes at present in the care of the history team will be transferred to Australian Archives ('AA' in footnotes) under the general access number CRS D 2412. Unless another specific locator is given in the footnotes, it can be assumed that the Archives will eventually house all the Australian primary sources used in this book. Sources of British origin held in Australia will be reviewed and, where possible, that material too will be transferred to the Archives. After the transfer, public access will be subject to the general provisions of the *Archives Act* 1983.

A NOTE ON NOMENCLATURE

All ranks and titles of persons, all names of countries, institutions, firms, government departments, committees, currencies, technical specifications etc., are given as they were at the time of the events described. Where a mention is not located in time the nomenclature is that current at the time of writing.

I have made only one exception to this. The organisation at Salisbury and Woomera which administered the work of the joint project in Australia went through a number of changes of name and apportionment of function over the years. When formed in London late in 1946 it was the Long Range Weapons Organisation (Australia), which on 4 October 1948 became the Long Range Weapons Establishment. On 14 January 1955 this was absorbed by the Weapons Research Establishment. Between 3 April 1978 and 1 December 1987 the title was the Defence Research Centre Salisbury and since then it has been the Defence Science and Technology Organisation Salisbury.

I have used these various names when speaking of events in the periods when they were current, but where no definite time is indicated I have simply referred to it as 'WRE' or 'the Establishment' (the Weapons Research Establishment) since that was the generic name of the whole facility for the lengthy period between 1955 and 1978. It should, of course, be borne in mind that not all of the work done at Salisbury or at Woomera was done under the auspices of the joint project, and this was more and more the case as time went by.

DISCLAIMER

All the judgments, evaluations and interpretations made in this book are the author's own, and do not necessarily represent the official views of the Australian Department of Defence, the British Ministry of Defence, or any other government department or its officers in either country.

PETER MORTON
Adelaide
South Australia
1989

Acknowledgements

The activities of the joint project involved the participation of thousands of people of several nationalities and diverse backgrounds. For more than thirty years the project saw many complicated tasks at the outer limits of engineering achievement going forward, some of them simultaneously. Most of them had high security classifications which meant that, if they were chronicled at all by the journalists and popular science writers of the day, it was only in the vaguest outline. Although there was a proposal in the early days to have the foundation of the Range documented and published (a title was even selected—the one used now) the plan was never followed through. Few people were aware of any obligation to the historian who one day would be peering over their shoulders trying to make sense of it all; and even if they had been, doubtless they were too busy to have done much about it.

It goes without saying therefore that this history, which is offered as a government-sponsored and authoritative account, could not possibly have been written without the assistance of dozens of consultants, especially those who sup plied drafts, and comments on drafts, for the author's use.

In first place I must thank the Director and staff of the Advanced Engineering Laboratory (AEL), DRCS for their unstinting help in securing access to papers and in helping me to deal with the Department of Defence and other Commonwealth government departments in Canberra. I am pleased to put on record that no barriers were placed on my going anywhere and talking to anyone at Salisbury, and I had free access to all the documents there which I wished to see. The Trials and Technology Support Division of AEL made available an excellent secretary, Mrs Theresa Van Der Walle, who worked for the team throughout and helped us cope with the huge correspondence generated as the book took shape. AEL itself generously supported my inquiries at Woomera, interstate and on four occasions in the United Kingdom.

I would like to record my special thanks to the staff of Computer Services Group, and in particular to Mr David McCloughry. David spent lots of his time teaching me how to use the mainframe IBM 4381 to best advantage, and was wonderfully adept at meeting my requirements for little programs to do this or that. Word processing and data management have much reduced the authorial and secretarial drudgery which formerly was intrinsic to such a large task as this. Indeed, it has opened up levels of consultation with experts and participants which have never before been possible. Since the text existed until the later stages of publication only as an image in the computer memory, it was an easy matter to send out endless drafts to informed parties, to emend the text with a minimum of effort and to keep the material under constant revision. Some chapters went through more than twenty 'editions' in this fashion. The text was set directly from computer disks supplied to the publisher, which greatly reduced the number of introduced errors and the subsequent proof-reading.

I am also grateful to my current employer, Flinders University, and specifically the School of Humanities' travel fund and the overseas conference scheme, for supporting my contribution to the bicentennial graduate seminar program at the Australian Studies Centre, London, in February 1988. A paper on the political background to the Blue Streak cancellation was read on that occasion and later published.

Of the several Australian government agencies which helped me at various points, I would like to thank the Federal Police and the Defence Security Branch for making files and details available on their work at Salisbury and Woomera; the Bureau of Meteorology in South Australia for information about the Giles Weather Station; and the Department of the Prime Minister and Cabinet. ASIO also released papers at my request and I found its staff pleasant to deal with and notably efficient in vetting drafts; my thanks particularly to an officer of ASIO's Adelaide office who must be anonymous. Also most helpful were the staff of three of the branches of Australian Archives: in Collinswood, SA; Mitchell, ACT; and Brighton, Vic. The Australian vetting of the manuscript was supervised by the Archives and Historical Studies (AHS) Branch within the Department of Defence; thanks particularly to Mr Arthur Skimin and Ms Joy Fox. Mr Dean Shuttleworth also played a substantial part. In

addition AHS made available to me a number of documents, particularly some files of the Shedden Papers, which were then in its care.

Outside Australia, I was helped by the staff of the Public Records Office at Kew, London. The National Archives and the Department of State, Washington DC, supplied information on US-Australian military relations in the period 1947-50, under their potent Freedom of Information Act. The European Space Agency's Publications Division at Noordwijk, Holland, supplied a useful and different perspective on the ELDO operations at Woomera.

Liaison with the United Kingdom, and specifically with the Ministry of Defence Procurement Executive (MODPE) which was my official channel of access to the British records on joint project activities, was through Mr W. T. S. Pearson, aided first by Mr Maurice Ashby and later by Mr Alan Jones. Tom Pearson, a retired officer of MODPE, was retained first as a paid consultant and later served as a voluntary and unpaid adviser and supervisor of the lengthy vetting procedure. In the early days of the task he undertook research for the team among the UK archives and forwarded his assessment of many key episodes. Later he provided comments on all chapters as they were forwarded to the UK. His diligence was matched only by Mr B. C. Kervell, Curator and Archivist of the RAE Museum, an enthusiastic and copious annotator of most chapters in draft, to whom I owe thanks for very many corrections of detail.

I would also like to thank Mr Roy Jarvis of MODPE whose straightforward approach did much to improve the flow of material to the history team, and also Dr John Tregellas-Williams, Defence Science Attaché at Australia House, for his diplomatic assistance. In Australia liaison with the British government was provided through the BDRSS organisation in Canberra, and I must thank Dr Roger Allen for his several cheerful intercessions on the team's behalf. The efforts of these people allowed me to include much information which hitherto had not been in the public realm.

Selecting the illustrations for the book from the vast collection of negatives and slides held by DRCS would have been a daunting job without the assistance of Mr Jack McDonald and the co-operation of the Still Photography Section, AEL; and Ms Annabel Frost of the Department of Defence. A general word of thanks is also due to those who gave copyright permission for the use of photographs, charts and cartoons. Thanks must also go to the drafting officers and illustrators in AEL who produced the diagrams, and especially to Mr Len Beadell for his cartoons.

The chapters on the early missile trials at Woomera and the evolution of the data-processing facilities at Salisbury benefited from material drafted by Mr Brian Polomka, and the one dealing with ELDO's program in Australia was based on an outline by Mr E. C. Montgomery. The late Lt Col George Foreshew was our most diligent unpaid volunteer, coming week after week to get down on paper his recollections of the flight safety story with which he was intimately involved. These are used in many different chapters.

Mr Ken Smith, late of the Royal Aircraft Establishment Farnborough and now retired in Adelaide, was responsible under a separate contract for drafting material on the guided weapons trials at Woomera, the Black Knight test vehicle, the Black Arrow satellite launcher, and the sounding rocket work at Woomera. I cannot praise too highly the work he did on these chapters: if they have any particular lucidity and accuracy it is owing to him. Nothing was too much trouble for Ken. He gave me many a lesson in the precise choice of a term and exactness of description, and when the time came for me to wield the editorial knife he took the criticism with high good humour and often showed me where to cut and reshape. A good scientific historian was lost when he made his career in rocket engineering.

Last, but really in first place, I owe an absolute debt to my friend, mentor and colleague, Mr Jim Frost of Trials and Technology Support Division, AEL. This is really his book as much as mine. After he took on the job of task manager for the history in 1981 it was his perspicacity in seeing what had to be done to get the book moving after it had languished for some years which was the single most important factor in its achievement. Jim's career at Salisbury and Woomera has spanned the entire joint project and his truly encyclopedic knowledge of it has helped me immeasurably at every turn. The three chapters on the instrumentation at the Range, that on the bomb ballistics work there, and the one on the air support for trials and transportation are in essence his work. The chapter on the origins of the joint project, on the WRESAT story, and on the Aboriginal controversy, are the products of our close collaboration. He also served as chief co-ordinator of the work on the illustrations and produced many of the diagrams himself. In truth, no chapter has not been touched by Jim's recollections and insights. After his years as task manager on this work, and now as he begins his retirement, no one more deserves to greet its publication with a fervent *nunc dimittis*. His calm, humorous and diplomatic manner has seen us through many difficulties together.

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Mr J. Byard, Mr M. King, Mr R. L. Ottens, Mrs M. J. Strauts, Mr V. Surman.

In Adelaide and South Australia:
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Mr A. G. Biggs, Mr I. C. Hinckfuss, Mr P. Jeffrey, Mr R. A. Macaulay.

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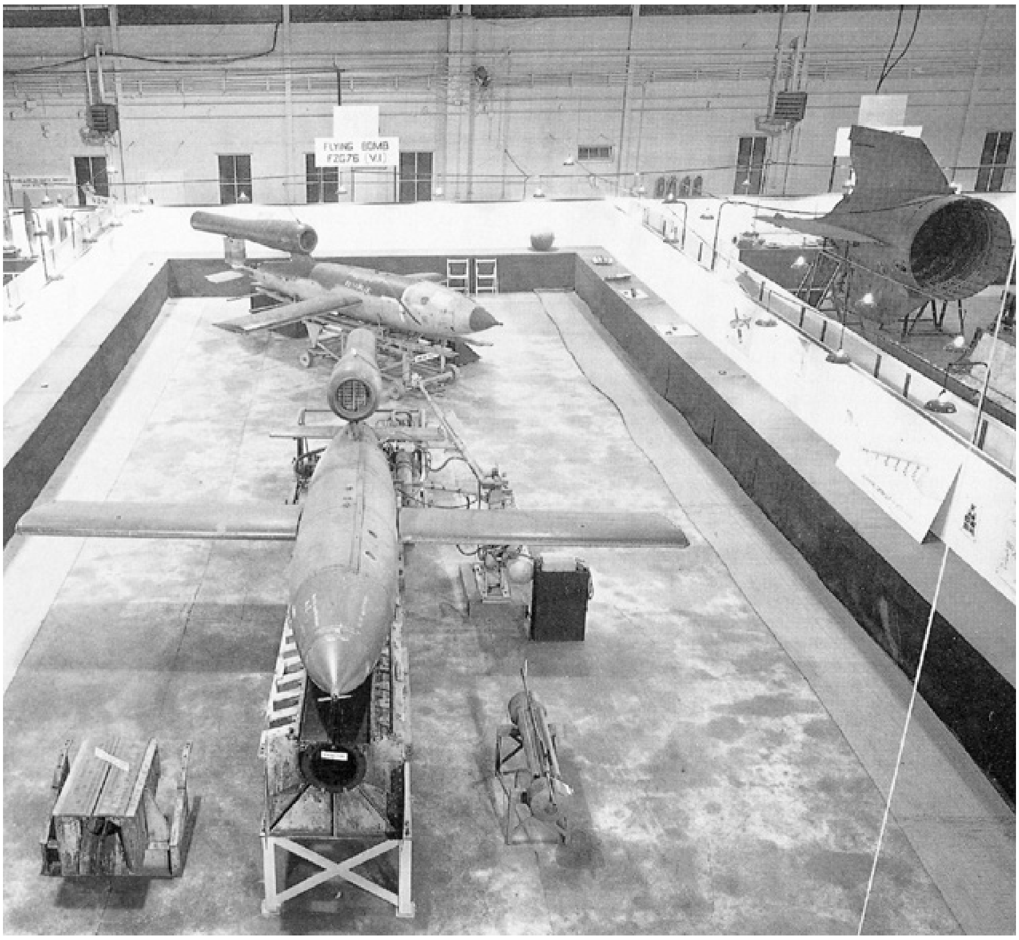
Mr A. Arnott, Mr P. Herden, Mr P. J. Oswald, Mr W. Pretty.

In Western Australia:
Mr D. Fern.

In Tasmania:
Mr Ray Barnes.

Part I: The Years of Establishment

This wartime damage in a London suburb was caused by a German V2 weapon, ancestor of today's intercontinental ballistic missile. Although not a decisive weapon in World War II, its revolutionary nature was a key factor in the British decision to set up a rocket range in Australia. (IWM)



Captured VI flying bombs on display at Farnborough in October 1945. At the right is a V2 tail section. (RAE)

1 Genesis: *The Origins of the Joint Project*

WARTIME PRELUDE

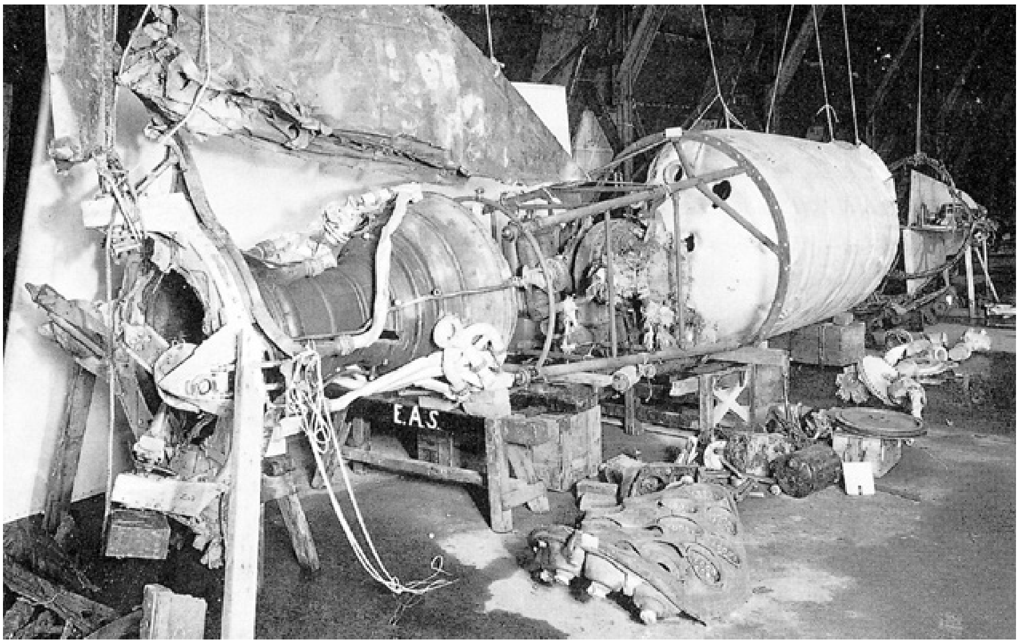
On the evening of 8 September 1944 a mysterious explosion rocked the London suburb of Chiswick, followed seconds later by another in Epping. It was the closing stages of World War II, and Londoners were no strangers to novel kinds of bombardment. They had already experienced the VI pilotless flying bomb in its thousands. When a VI arrived over the target it switched off its loudly pulsing jet engine, and the brief ominous silence as it dived to the ground was broken by the roar of its detonating warhead. But this new weapon was different. The sonic boom of its approach was only heard after the explosion, by the survivors. There was no air raid warning, no engine noise, no time to take cover—just a sudden destructive blast from the skies. Small wonder that the British public was mystified for the next two months, until the government revealed what it already knew. Hitler's second 'retaliation weapon' had come at last, and it was the world's first long range ballistic missile to be used as an agent of war.

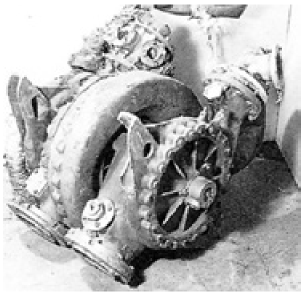
The V2 bombardment of London (a few landed elsewhere in the country) lasted just under seven months and killed over 2700 people. Such a destructive power is hardly memorable in the bloody annals of World War II. The Allied bombers over Dresden in February 1945 killed tens of thousands in a single night. No, the importance of V2 lay not in its destructive power but in its range and speed and the promise inherent in its design. For it was the harbinger of a new kind of warfare: a war of technicians, not of soldiers; a war where an aggressor could sit snugly at home and point his finger of force against another country. The rocket which exploded at Chiswick had been fired a few minutes before from The Hague in Holland; and earlier in the day another V2 had been launched from the same place against newly liberated Paris.

Lord Cherwell summoned to No. 10 Downing Street in 1940. (Hulton)

As early as April 1943 British intelligence had become aware that on the Baltic coast, at a place called Peenemünde, some kind of rocket was being built and test- fired into the sea. The first reports were vague and their reliability questionable. Aerial photographs taken by reconnaissance planes were ambiguous too, and many months passed before the real degree of threat was grasped in London. The notion of a ballistic missile able to carry a large warhead across the Channel was so revolutionary that at first Churchill's eminent scientific adviser, Lord Cherwell, refused to believe it. He argued that the intelligence reports were disinformation put out to conceal the development of some other weapon. Cherwell's caution is not surprising. At that time all the Allies had in the way of military rockets were the Z-weapons, which despite their sinister name were only 127 millimetre solid propellant unguided missiles deployed with moderate success against enemy aircraft. How could the Germans possibly have rockets well over a metre across, weighing tonnes and capable of bombarding London from 300 kilometres away? It sounded like science fiction. The War Office's proper appreciation of the German achievement was also handicapped by the views of Dr Alwyn Crow, then Controller of Projectile Developments at the Ministry of Supply (MoS). During the deliberations of the Bodyline Committee, set up by Duncan Sandys to examine all the evidence, Crow helped to reinforce the authority of Cherwell. Both scientists argued that the only practicable rocket fuel was cordite burnt in a thick steel case. To carry a heavy warhead across the required distance such a rocket would have to be a monster: it would probably need four stages and weigh anything up to 100 tonnes. Neither man would entertain the possibility of a liquid propelled rocket, even though not long before Crow had seen two demonstrations of Lizzy, an engine which burned aviation gasoline in liquid oxygen (LOX), built by a Shell engineer, Isaac Lubbock, whose company had a small research

A V2 reconstructed from wreckage at Farnborough in early 1945. (RAE)





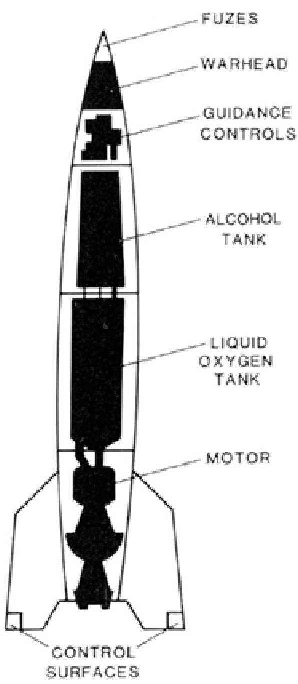
The steam-driven turbine and centrifugal propellant pumps from a recovered V2, December 1944. (RAE)

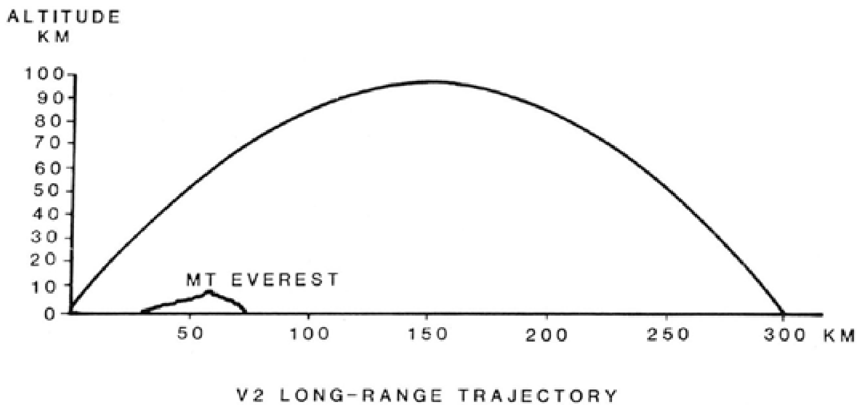
contract to develop an aeroplane booster.[1] For their part the Germans had abandoned solid fuels for ballistic missiles well before the war, when they started to design what became the V2.

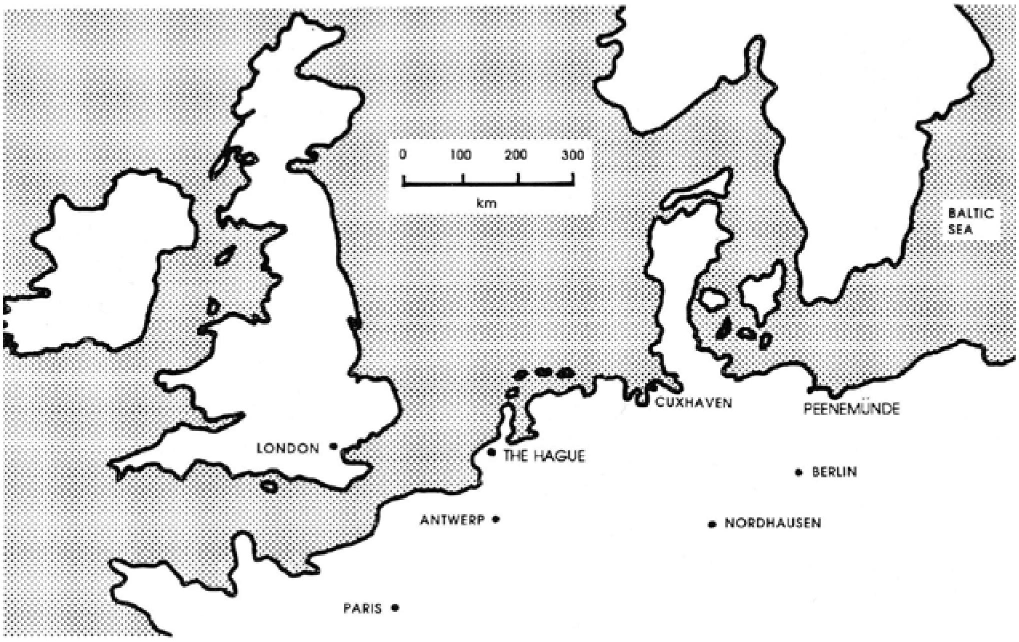
In August 1943 Churchill had ordered a massive bomber raid on the Peenemünde installations, but although this delayed and dispersed the German work it did not stop it. For almost a year the rocket threat to Britain was pushed into the background by the onslaughts of the VI flying bomb. It was not until July 1944 that a straying experimental rocket landed in a Swedish bog and its transfer to Britain was negotiated. Experts at RAE, the Royal Aircraft Establishment at Farnborough, were at last able to examine physically the two tonnes of wreckage. As they laid out the parts in a hangar and painstakingly fitted them together, they grew astonished at the sophistication of its design. In particular, the Germans had brilliantly solved the problem of pumping the propellants to the combustion chamber by devising a turbine driven by chemically generated steam. This ran two powerful centrifugal pumps, and in fact it was the generous tolerances in one of these that had pointed to the use of LOX as one of the propellants. In its report to the Crossbow Committee (successor to Bodyline), RAE confirmed that the rocket which its staff had reconstructed did indeed have the power and range to reach London from enemy territory in Europe. This evaluation was grimly confirmed with the first casualties in the following month.

The German A-4 (V2) rocket was 1.6 metres in diameter and 14 metres long, weighed 12 tonnes and could deliver a tonne of high explosive over a range of at least 330 kilometres. A mobile unit of trailers and tankers could launch it from any flat solid surface such as a sealed road. Burning alcohol in LOX, the V2 was guided during the propulsive part of its flight by an unjammable autopilot. After its propellants were exhausted it travelled in a free-fall or ballistic trajectory well above the atmosphere and then plunged downwards to its target at thrice the speed of sound. The earlier VI bombardment had eventually been neutralised by a combination of RAF fighters, radar and anti-aircraft gunnery defences, but

The liquid propelled V2 rocket and its ballistic path. A V2 could deliver a tonne of high explosive over a 330 kilometre range.







The V2 was largely developed and test fired at Peenemünde on the Baltic coast, as was the VI flying bomb, but, after a massive British air raid, manufacture was shifted to an underground factory at Nordhausen. London was bombarded by V2 weapons launched from The Hague.

the V2 was beyond attack as soon as it was launched. It was the direct ancestor of today's intercontinental ballistic missile.

Under the spur of war Britain had made astonishing advances in radar and had at least kept pace with Germany in developing jet propulsion. In partnership with the United States it was building an atomic bomb. The Allies' air superiority was total by this stage of the war. But the stray V2 proved that the Allies were far behind the Germans in rocket technology. Faced with the mounting evidence of this gap, and later with the new threat in the Pacific war of Japanese kamikaze suicide bombers, the Allied High Command resolved that some effort should be diverted to the research and development of guided missiles, and this work began in 1944. The first step was to find out as much as possible about the German developments.

The bombardment of London lasted until March 1945, two months before the Germans were ousted from Holland and their V2 launching sites overrun. As British forces swept on towards Berlin an enthusiastic hunt began for the technical secrets of the advanced German weaponry. It soon turned into a race to get to the factories before the Russians.[2] For the British it also developed into a race to get there before the Americans, even though the Allied Chiefs of Staff had ordered that British and American efforts should be co-ordinated to secure these precious trophies of war. In the event the US Army got to the centre of the hive first when on 1 April 1945 they captured the huge underground Mittelwerke factory near Nordhausen in the Harz Mountains, where most of the V2s had been manufactured using slave labour ever since the Peenemünde raid in 1943. Then a few days before VE Day, 8 May 1945, the German scientists who had led the development of the V2 at Peenemünde, including Wernher von Braun and General Walter Dornberger, gave themselves up to American troops in the Bavarian Alps.

British scientists took part in the interrogation of the Peenemünde team. They had already examined captured mechanical and electrical components of the rocket, and RAE had published reports on them by May 1945. In early May came discussions between the Allied Headquarters, the War Office and Sir Alwyn Crow on a proposal to use German experts to fire captured V2s in Germany, to establish exactly how this was done before the technicians dispersed or lost their skill. The consequence was an Allied military operation known as BACKFIRE. As the firings were to be seaward from Cuxhaven on the North Sea coast of Germany, which was in the British occupied zone, Operation BACKFIRE was organised by the British Army and commanded by Major General A. M. Cameron, with support and technical assistance from the Ministry of Supply. The US Army were invited to participate, but it did no more than provide observers. It had its own far more elaborate plans for the V2, which involved firing it in quantity from the White Sands Range in the New Mexico desert.

Securing enough V2s and their support equipment proved a major headache for Cameron and his team. US Army ordnance officers had dug deep into the Mittelwerke factory at Nordhausen, securing enough parts for a hundred complete V2s before that part of Germany was handed over to the Red Army. By the end of May the components had been railed to Antwerp and loaded aboard a fleet of Liberty ships. They were on their way to the New Mexico desert by the time the British protests arrived.

The American officers at Nordhausen told Cameron that the factory still contained plenty of rocket equipment, enough to supply thirty V2s for BACKFIRE, as well as the 120 requested by the Air Ministry. Before the deadline of 21 June ended their access to the factory, the BACKFIRE team recovered and railed to Cuxhaven an impressive 650 tonnes of equipment. But the quantity was deceptive. The Americans had skimmed the cream and many of the complex sub-assemblies were missing altogether. The team scoured northern Germany, collecting components and damaged rockets from factories and railway yards, from canals and ditches and fields where they had been abandoned by the retreating troops. Ground equipment was located by interrogating prisoners of war, and often dug up from where it had been buried. By the middle of September enough equipment had been collected, repaired and assembled to produce just eight V2s fit to fire, although a complete set of the remote control equipment was never found.

The work of rebuilding and launching the V2 rockets was done by a 600-man German unit under British Army supervision. The unit included 137 officers and regular soldiers selected from the surrendered A-4 Division of the Wehrmacht. These soldiers were supplemented by seventy-nine German civilian scientists and technicians of the old Peenemünde team who were borrowed from the US Army. To counter possible deception, some of the Peenemünde experts were kept in a separate team and used only to cross-check information supplied.

At the first attempt on 1 October 1945 the engine did not fire and the launch was temporarily postponed. Certain repairs required a mechanic to climb right inside the combustion chamber and, according to reports, this intrepid man became helplessly drunk on the fumes of the alcohol fuel pouring down inside. Finally, after several more abortive attempts, three of the eight rebuilt rockets were successfully fired into the North Sea, and two of them landed close to the target. They were tracked by radar and by Askania kinetheodolites, optical instruments of the same make as those which some years later were installed at Woomera. The first guided missile trials in which Britain had participated proved quite successful. BACKFIRE provided valuable experience in the handling of liquid propellants, an experience that was to be drawn on a decade later for the first of the big Woomera-launched rockets, Black Knight. It also brought home a better appreciation of both the capabilities and the limitations of the V2.

In his lengthy report issued in January 1946, Cameron concluded that his objective had been achieved and that it was impossible to exaggerate its significance:

> Whatever the future may hold, the A-4 is undoubtedly already a feasible weapon of war. Even if Britain and the United States do not wish to use it, they must at all costs be prepared to counter it. Efficient and up-to-date countermeasures cannot be produced without developing the weapon itself.
>
> The lesson of operation BACKFIRE is that what Britain and the United States can do, other nations can do. No nation can afford to allow the development of long range rockets to jog along as a matter of routine. There is need of all the imagination, drive, and brains that can be mustered. For the sake of their very existence, Britain and the United States must be masters of this weapon of the future.[3]

Written at a time when devastated Europe had barely begun to count the cost of the war, Cameron's words could hardly have put more succinctly the reasoning behind the joint project, then in the first stages of its gestation. The Allied leaders were quick to realise that two events on opposite sides of the world—the V2 at Chiswick on 8 September 1944, and the bomb on Hiroshima on 6 August 1945—had transformed military science as never before. During the war 3000 of the two V- weapons fell on and around London. They did a lot of damage but were not very cost-effective, especially the V2. Antwerp received no fewer than twenty-six V2s in a single day, yet even this failed to bring the port to a standstill. It would have been a very different story had it been possible to arm them with Hiroshima-size atomic warheads. Just a few such warheads, each with a yield of 22 kilotonnes, would have devastated London and altered the course of the war. No one doubted that the marriage of these two weapons, fearsome enough separately but of appalling potential when united, had only been postponed, not cancelled.The last of the three V2 firings at Cuxhaven had

A V2 that came to Australia on display at a Salisbury school.

been used as a semi-public demonstration attended by the press and representatives from the United States, the Soviet Union and France. Probably it was intended to show that the Allies had indeed unlocked the secrets of the V2, but its broader effect must have been to send away the onlookers in a very thoughtful mood.[4] Certainly none of their governments was slow to grasp the potentialities of the ballistic missile. Although the British were mainly responsible for this demonstration, it was the Americans and the Russians who between them seized most of the valuable spoils of war. As well as their hundred V2 rockets the Americans acquired thousands of technical documents; they also took to the United States most of the key Peenemünde engineers, including von Braun, in an operation code-named OVERCAST (later PAPERCLIP). These men became the nucleus of the US Army ordnance team that went on to develop Redstone, then the Jupiter-C booster that launched America's first satellite, Explorer 1, and finally the giant Saturn V rocket that put the first man on the moon. To the Russians fell the Mittelwerke factory, the remnants of Peenemünde, and most of the other rocket engineers. Since Nordhausen was in East Germany they were able to revive production there under the guidance and control of engineer Dr Helmut Grötrupp, and probably a thousand or more V2s eventually went back to Russia for experiments. Though the Russians did not get the most talented men, they made the most of their inheritance by going on to develop their own InterContinental Ballistic Missiles (ICBMs), to launch the first artificial satellite, and to make the first manned orbital flight.

To the other victors, the British, went far fewer spoils. They had solved the secret of Hitler's secret weapon and alongside the Belgians had withstood the world's first bombardment by guided missile; but all they were left with was a few V2s remaining from BACKFIRE (one or two of which later arrived in Australia) and several capable Germans who went to work at RAE and other establishments.

BRITAIN FACES THE GUIDED MISSILE AGE

With World War II over at last, Britain faced up to the mountainous economic, political and military problems that were its legacy of the conflict. It took some time to come to terms with these, especially the country's diminished economic status and hence its position as a world power. Some of them were to beset Britain for years afterwards, profoundly influencing the joint project throughout its existence.

Economically, the country was in a parlous state, yet money was needed for pressing and widespread reconstruction. Houses had to be built, the transport system renewed and factories converted to peacetime production. Agriculture and fisheries needed revitalising before food rationing could be phased out; indeed, bread rationing was introduced for the first time after the war ended. Much of Britain's wealth had been dissipated in the long struggle, especially the valuable investments abroad which had been the glittering prizes of Empire. Gold and dollar reserves had been cut in half. A third of the mercantile marine was at the bottom of the sea. The years of war had all but dried up capital investment in the home industries. Paradoxically the factories of Britain, with their stock of ageing and obsolete machinery largely intact, proved to be more of a handicap in the long run than the devastated factories of Germany and Japan. Those countries had to make prodigious efforts, but they were able to invest from scratch in the newest equipment, and their productive energy soon transformed the shape of Britain's traditional export market. Only American aid in the shape of the Marshall Plan kept the country solvent in the immediate post-war years.

Politically, Britain had to take some urgent overseas initiatives. She had to help build up the United Nations, participate in the continuing occupation of Germany and try to help stabilise the fluid political scene not only in Europe but also in South-East Asia and the Pacific following the sudden collapse of Japan. The Empire also needed radical changes; as it had promised to do, Britain had to disengage itself from Burma and India.

Militarily, the Eastern bloc had arisen as the main threat in place of the defeated Axis, and this was to lead to the creation of the North Atlantic Treaty Organisation (NATO). Britain found it impossible to dispense with conscription even though this kept out of productive work enough able-bodied workers to man a large industry. At the same time, the officers of the British armed forces had to recognise that conventional armies, guns, tanks and battleships were no longer enough. The lessons of V2 and Hiroshima could not be ignored; military planning would have to be thoroughly revised. The Soviets had the Nordhausen factory and could be expected to go all out to develop long range guided missiles. Sooner or later they would be carrying nuclear warheads.

Faced with the realities of post-war international politics and military technology, and barely questioning the dogma that the country must continue to be a world power, Britain faced up courageously to the fact that resources would have to be found for rearmament, and rearmament on a grand scale. An enemy in sole possession of a long range ballistic missile armed with a nuclear warhead would have the heavily populated, highly industrialised United Kingdom at its mercy. The same was true of other European countries, but the British, those offshore islanders, had traditionally relied on their navy for defence. In a war fought with guided missiles the country could be defeated before a single ship had left port. Their new vulnerability was thus felt the more keenly.

If no defence were possible against the guided missile, the only hope was to deter an aggressor by the threat of swift and certain retribution. The new Attlee Labour government decided that it must have the new weaponry no matter what the cost. The development of a British nuclear bomb began in 1947 and continued unabated long after the first test at Monte Bello off Western Australia in 1952. The cost was indeed great, for Britain had to draw entirely on its own resources, the McMahon Act passed by Congress in August 1946 having prohibited the US from sharing atomic secrets with its wartime allies. But the bomb was only part of the burden. Britain also chose to expand greatly the program of guided weapons development that had begun so uncertainly, late in the war.

Though these programs of rearmament and military research were deemed vital for national security and had popular support, they still had serious repercussions. Spending money on the armed forces has never been popular in Britain and before the war expenditure had generally been less than 3 per cent of the Gross Domestic Product. But, as the nation entered the 1950s, the cost of defence rose to 7.5 per cent of the GDP in 1951 and then, with the mounting tensions of the Korean war, to an unprecedented 8.7 per cent the following year. This was a higher proportion than in any other Western country, and as a historian of the period has written, 'the economy creaked and groaned under the pressure of the shift to military production'.[5] At first the opinion polls showed that rearmament commanded considerable popular support. Even when asked to choose directly between rearmament and housing, a commodity in terribly short supply in 1951, the respondents were almost equally divided as to which should come first. But the burden grew very heavy over the next few years, especially because rearmament called for more aircraft, vehicles, ships and electronic gear, and therefore absorbed a good deal of the most valuable kind of capital investment which could have been of more direct social benefit. It also absorbed the energies of an actual majority—nearly two-thirds, on some calculations—of the country's most talented engineers and technicians. This realisation was reflected in the polls. By 1955 a large majority was opposed to any further increase in spending on armaments; most thought the prevailing level was about right.[6]

The decision to develop guided weapons having been taken, the immediate task was to set up an organisation, more formal than the *ad hoc* arrangements of 1944, to administer the research and development effort. At first the work had been divided up along traditional service lines. Research into 'aircraft-like' and air-launched missiles was assigned to the Ministry of Aircraft Production (MAP), the body set up just before the Battle of Britain to develop and build warplanes. Ship-launched missiles became the province of the Admiralty and ground-launched missiles of the Ministry of Supply (MoS) which at that time looked after the needs of the War Office (Army). A 'Guided Anti-Aircraft Projectile Committee', known as the GAP Committee, was set up in March 1944 to co-ordinate Admiralty and MoS efforts. The GAP Committee oversaw the research into the basic arts of rocketry—propulsion, guidance and instrumentation—which was going forward at some ten MoS scientific establishments. The GAP Committee's work was strongly practical and oriented towards quick production. By contrast MAP, in charge of airborne weapons, had a rather different philosophy. It wanted to do a lot more basic research before embarking on weapons production. In particular it felt it needed to develop test instruments and simulators to allow the behaviour of missile systems to be measured and predicted. Their work was conducted by RAE and by the Telecommunications Research Establishment (TRE), which were both controlled by MAP at the time.

One job undertaken by the GAP Committee was to draw up the first military staff requirement for a guided missile. This was for a medium range weapon capable of attacking fast, high flying bombers. The shopping list quickly grew: air-to-air missiles with which fighter planes could attack bombers; an expendable pilotless bomber; a V2-type bombardment ballistic missile of up to 500 kilometre range; and a very advanced winged missile capable of reaching across Europe. And the military forces wanted these things soon—in three years or less. Their ambitions were dampened for a while by the report, issued in June 1945, of a secret committee chaired by Sir Henry Tizard, the government's eminent scientific adviser on military matters. The report took a cautious line on the supplanting of manned aircraft by guided missiles, observing that 'there is a tendency to attach too much importance to the possible substitution of human beings in aircraft by automatic mechanism. A highly trained man is more flexible than any automatic device.' It predicted that the major defence of cities and convoys would rest with supersonic fighter planes supplemented by ground-to-air missiles. Influenced no doubt by the success of the V2, Tizard saw a place for ballistic missile bombardment over a range of 650 kilometres or so, observing that V2-style rockets would continue to be very hard to counter. By contrast the strategic bombing by aircraft, as used to such effect during the war, would be too costly once supersonic fighters had entered service. However, Tizard thought long range guided missiles were many years away. Ranges even of 3000 kilometres were possible in theory, but for each additional tonne of warhead the launching weight would rise by 100 tonnes. Pilotless aircraft would be more efficient by a factor of ten, but in both cases there were daunting problems of terminal guidance. Tizard concluded that, 'there is little reason yet to believe that the effort will be worth the cost'.[7]

It is evident that the Tjzard report was a very conservative document. Its authority was vitiated by the fact that Churchill refused the committee access to atomic information, and its deliberations were concluded by the time the Hiroshima and Nagasaki bombs were exploded. Though the report has some shrewd remarks about the future significance of nuclear weaponry, it does not comment on the potentialities of guided missiles with atomic payloads. This may have hindered its later acceptance in policy making circles, and personal friction between Tizard and Crow may have played a part too. Whatever the reason, the Tizard report was against the tide of the times and its conclusions on guided weapons were virtually ignored over the following year or two.

It was inevitable that the divisions of function and philosophy in MAP, MoS and the other ministries should spell administrative confusion and duplicated effort. After a review early in 1945, the split of responsibility for new weapons between MoS and MAP was clarified. Within MoS a new Directorate of Guided Projectiles (DGP) was created in July 1945, to control research and development of ship- and ground-launched weapons for the Admiralty and Army. The new Director was Sir Alwyn Crow, and he took over the work of the GAP Committee, which was dissolved. An interdepartmental committee was also formed, to co-ordinate this MoS work with that of MAP on air weapons.

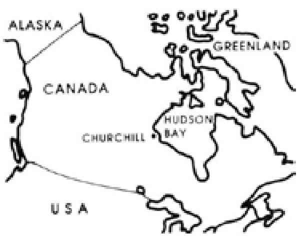
Crow also moved to set up a new Guided Projectile Establishment at Westcott in Buckinghamshire to be a focus for work on guided weapons in other establishments, and to carry out work not already catered for, particularly into the chemistry of propellants. After the foundation of Westcott in April 1946, static test-firing stands were constructed and the engineers buckled down to the manifold problems of rocket design.

Just after the end of the war the government decided to absorb MAP into an enlarged Ministry of Supply, which now was given the responsibility of supplying weapons to all the armed services. However, the split between air and other weapons was preserved at a lower level until November 1946, under two separate Controllers of Supplies, one for Air and the other for Munitions. This gave the new Ministry something of a split personality when it came to guided weaponry, a split which was to emerge again later. The Munitions side of MoS, particularly Crow himself, was not inclined to give much weight to Tizard's analysis. It favoured pushing forward quickly with guided weapons, continuing from where the Germans had broken off at the end of the war. The Air side of MoS continued to be more interested in developing the techniques of propulsion, guidance and aerodynamics before embarking on the production of service weapons. The Munitions viewpoint prevailed at this stage. Just as Cameron had recommended in the BACKFIRE report, the British government determined to produce a selection of guided weaponry with the utmost priority and at any cost. But once built, the missiles had to be tested. For this Britain had to have a rocket range, and it needed to be a good 1600 kilometres long to accommodate the transcontinental flying bomb.

EYES TURN TO AUSTRALIA

No one doubted that Britain's rocket range would have to be overseas, on the broad terrain of a friendly nation. Nowhere in the British Isles could rockets be fired safely over even a tenth of the required distance. The few weapons ranges in Britain had been designed for short range gunnery, for bombing practice, or for testing small unguided rockets. Most of them ran over the sea, making recovery of the remnants awkward, and in any case the climate ruled out long distance optical observations. So late in 1945 Crow and the defence planners took a hard look at several possible locations. They were not looking for a range site alone. They saw advantage in having the actual production of military hardware dispersed abroad, as had been done in the later phases of World War II, in order to lessen the risk of disruption from enemy attack. Perhaps Britain and the host country could help each other to design and produce weapons. The obvious place for Britain to look for partners in such a joint venture was the British Commonwealth: the dominions of Canada, South Africa, Australia and New Zealand. Britain already had a share in a nuclear plant in Canada and a chemical warfare establishment at Proserpine in Queensland. Dispersing the production of guided weapons over these distant countries would make communications difficult in an emergency, but it also made it hard for an enemy to knock out all production simultaneously.

It was soon apparent that for practical purposes the choice of a Commonwealth country for a missile range narrowed down to Canada or Australia. Only these two were politically uncomplicated and possessed enough unpopulated territory for a long range overland. (A third possibility was briefly canvassed of a sea range in the Bahamas, but rejected because recovery would be difficult, and because the area was heavily populated, thus posing security and safety problems.) The choice, then, was Canadian tundra or Australian desert. The advantages of Canada were that it was close to the United States and relatively so to Britain too; it was also more industrialised than Australia. However, 1300 kilometres of Hudson Bay tundra was about the most that Canada could offer. This terrain would be snowbound through the long winter, meaning that for a large part of the year visibility would be poor and recovery of the expended missiles difficult. Nevertheless, Canada was being seriously considered in the second half of 1945.



The Hudson Bay area of Canada was seriously considered as a site for a British Commonwealth missile range in 1945 but was rejected in favour of Australia with its more suitable weather.

Australia was a very different proposition. It had the disadvantage of being an immense distance from the Western power centres, although the need for absolute security made isolation an equivocal factor. On the positive side, the task of finding in the vast empty interior of the continent a stretch of desert even 1600 kilometres long did not seem onerous, and an extra length over empty sea could easily be added on at many points around the coastline. Surface communications in the outback were less than ideal, but roads would be easy to build across the flat and rainless land and a rail link to the rangehead appeared possible too. Industrial support could come from the cities of the settled south-east. The heat, flies and occasional sandstorms would be troublesome to the staff for a few months in the year, but most of the time the climate would be ideal and the clear desert skies would be superb for optical tracking. Trials could go on all the year round. Finally, Australia was an affluent country with little war reconstruction to do, and politically it was extremely stable and one of the most loyal members of the Commonwealth.

At that time Australia had a representative of the Munitions Department posted in London. His name was William Coulson. He and Crow had joined in firing small air-launched rockets at the Aberporth range in Wales, and Coulson had often urged the advantages of his country, which he was sure could meet the requirements for a range. Matters came to a head in September 1945. Coulson persuaded two high officials of MoS that an agreement on the point of being negotiated with Canada should be postponed while he put his ideas to his superiors at home. According to Coulson's own account:

> At this meeting [with the MoS representatives] I tabled a map of Australia on which was marked a range area based on a rangehead at Mt Eba in South Australia, firing in a north-westerly direction crossing the coast between Port Hedland and Broome. (This map, the first to show the Australian Rocket Range, was still at Australia House in 1950, and may be there to this day.)[8]

Coulson's next step was to fly to Melbourne to report to his chief, Noel Brodribb, Controller General of Munitions. At the Victoria Barracks on 16 October 1945 Brodribb and Coulson explained the scheme in detail. Present were the three Chiefs of Defence Force Staff; Frederick Shedden, Secretary of the Department of Defence; and Sir David Rivett and Dr F. W. White of the Council for Scientific and Industrial Research (CSIR, later CSIRO, the major civil scientific research organisation which it was then assumed would be working for the project). Of these, Shedden's voice was perhaps the most influential. A senior public servant of great experience and authority, Shedden was very fond of the role of grey eminence. Once he had put his weight behind the proposal, general acceptance quickly followed and was recorded in these terms:

> Sir Alwyn [Crow] is anxious to ascertain the view of the Australian Government on a suggestion by the British Government that guided projectile research should largely be moved from the United Kingdom to Australia, in order to take advantage of the exceptional facilities offered by this country's empty spaces, combined with her intensive production ability.[9]

The Minister for Defence, John Dedman, then consulted Prime Minister J. B. Chifley. Both agreed to recommend the Crow-Coulson plan to Cabinet when it was submitted formally, with the proviso that satisfactory arrangements would have to be worked out between the governments covering such matters as Australian participation in the work, the access to information, the financial details, and how the undertaking was to be controlled. In general, though, the Australians believed strongly in defence co-operation and were eager to strengthen the bonds of Empire.

One should not interpret Chifley's quick acquiescence as simply answering the call of the Mother Country. Even in 1946 Australian loyalty was not quite as blind as that. A good deal of self-interest was at work. We should recall that the Labor Party had been in power in Australia ever since the early years of the war, and it had borne the heavy responsibility of administering most of the war effort. Its Ministers remembered only too well that in the desperate days of 1943 Australia had asked Britain for armaments to use in the Pacific theatre, only to be denied them because they were needed in Europe. Chifley was thus very interested in Australia's acquiring its own versions of the new generation of weapons for use in any future war. The British proposal seemed to offer that, and more; it might lead to Australia's becoming the arsenal for the whole Empire. If the British weapons research effort were moved wholesale to Australia the consequences could only be good. Many highly desirable people would migrate with it. The economy would receive a general boost from the influx of money, the establishment of new industries and the encouragement of scientific research. Australia clearly stood to benefit provided an acceptable agreement could be worked out on how the control, work, costs and information were to be shared. This was not Chifley's opinion alone, but very much that of his advisers too. A few months later, when the proposal was beginning to take shape, Brodribb told him confidently that

Australian Prime Minister J. B. Chifley. He strongly supported the project when it was first mooted in 1945 and later formally accepted it. (PA)

> it has been accepted in the United Kingdom that within a period of a few years there will inevitably be an almost complete transfer to Australia of research and development associated with this project. This ultimate transfer will without question put Australia in the very forefront of the most modern developments in Defence Science.[10]

In the light of subsequent events both the British proposal and the Australian reaction to it appear rather naive. The idea of a united Empire defence started to look quaint with the granting of independence to India and Burma and the rise of nationalism in Egypt, Palestine and Ceylon. Britain eventually abandoned even the semblance of Commonwealth defence by withdrawing west of Suez and largely restricting its military forces to Britain itself, Germany and its NATO obligations. No massive transfer of guided weapons research, production or staff ever flowed from Britain to Australia. The benefits of the Anglo-Australian joint project to Australia, though real, were more dispersed and tenuous than that. Nevertheless, the two countries saw the project from the beginning as truly a joint undertaking in which both would take full part and from which both would benefit. This philosophy, though problematic from the start, was strong enough to survive several changes of government in both countries, and a number of searching reappraisals and renegotiations in the years ahead.

THE EVETTS MISSION

When Coulson returned to London with good news from his masters, the British decided to send a formal mission to Australia to discuss in detail how the Range should be set up. As they started to plan for this, an unexpected opportunity arose to garner some more information at little cost.

Lt Col John Caddy was a member of a small team that had preliminary discussions on the project while visiting Australia in early 1946. Later he was one of the Evetts team that established the project.

It was now the end of 1945. It so happened that a small team was about to embark on an overseas tour to study how far military production could be distributed among the Commonwealth countries. It was led by H. W. L. (later Sir Leo) Kearns, a high-ranking officer of MoS in charge of machine tool production. The other members were a Mr Harrison (also from MoS) and Lt Col John Caddy (later one of the 'Evetts eleven' who moved to Australia to administer the project). The Kearns team were going to visit India, Ceylon, Australia and New Zealand. While in Australia they could easily take a preliminary look at the country and talk about the proposal with some officials. This they did. Whether by accident or design their port of entry was Exmouth on the north-west coast of Australia, and from there they flew diagonally across the continent. They were fascinated by the red earthy desert unrolling hour after hour like an endless loop of cinema film beneath the wings of their aircraft; a featureless expanse relieved only by rocky outcrops and ridges, utterly bereft of towns, railways or important roads. If you wanted to fire experimental rockets then here, surely, was the country to do it in.[11]

Perhaps as a result of the favourable reports brought home by the Kearns party at the turn of the year, the British government was able to be quite specific about its requirements when, in February 1946, it formally requested Australia to receive its mission. The letter began by defining the ideal requirements for 'a large area in which trials with guided weapons can be carried out'. The area should be about 1600 kilometres long by 300 kilometres wide at the target end, easily accessible by road and rail to the firing point and yet easily protected against prying eyes. It should be flat, easily surveyed and in an area with an equable climate. It should be within reach of a suitable research organisation and of an industrial zone where components could be manufactured efficiently and securely. If the mission left very soon its work would be done in time for an informal conference on defence science scheduled for June. This conference, chaired by Tizard, would be attended by officials from all the Commonwealth countries. The British were eager to seek Commonwealth support, and perhaps involvement, in what they were planning to do in Australia.

After receiving approval, preparations went ahead for the visit, now formally entitled 'The Mission to Australia in Connection with Guided Projectiles'. The official briefing called upon the mission 'to obtain the best possible range in the British Commonwealth, and to make a general survey of the industrial and technical facilities to enable full scale firing trials to be carried out of all types of guided projectiles'. It was to 'endeavour to reach satisfactory understandings with the Australian Government' on a number of matters including Australian participation in the work of the Range and the possible future Australian production of guided missiles. The mission was ordered to be circumspect in talking about money:

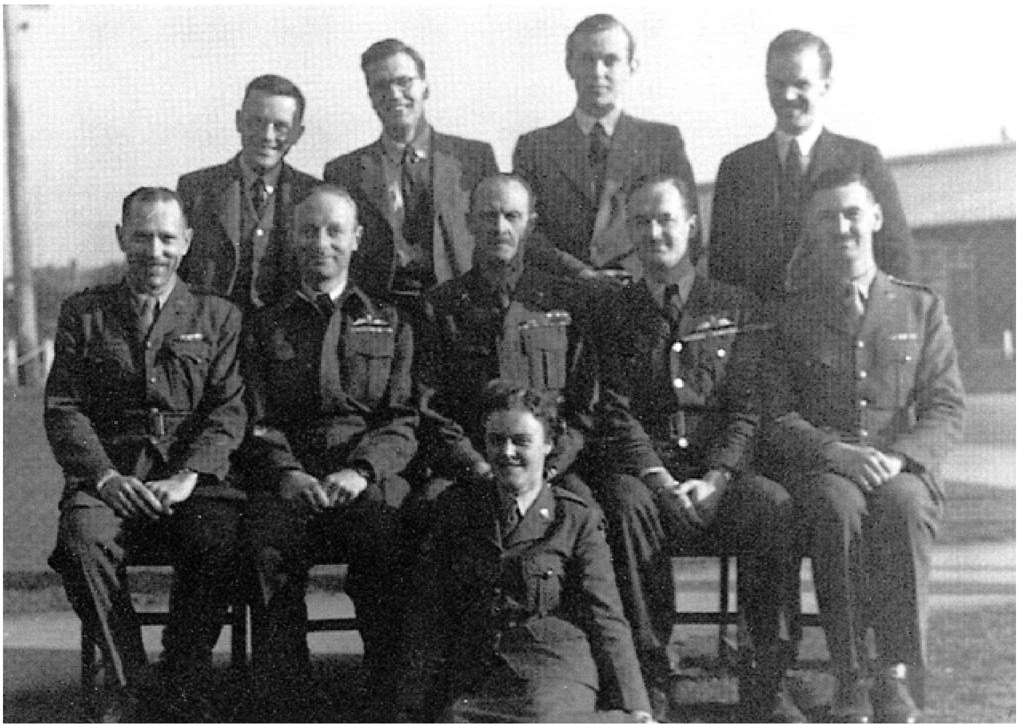
> At this stage, the mission should do no more than invite the Australian Government to agree in principle to bear some part of both the capital and maintenance cost of the range; and take note of any proposals from the Australian Government as regards the amount of the contribution or the form which the contribution might take.[12]

The initial proposal was for Sir Alwyn Crow to lead the mission. In the event it was led by the Senior Military Adviser to MoS, Lieutenant General J. F. Evetts, CB, CBE, MC. Apparently Evetts was not entirely happy with this assignment, feeling he was the wrong man for the job.[13] His fears were baseless. Evetts went on to do more than any other individual in fostering the growth of the project in its first few years.

John Evetts, tall, genial and sufficiently debonair to be known in the ranks as 'flash Jack', was neither scientist nor engineer but a career Army officer. A graduate of Royal Military College Sandhurst, he had been in the Army since 1911 and was decorated with a Military Cross during World War L Between the wars he was stationed in the Middle East for some years, where he was employed by the Iraq Army from 1925 to 1928 and afterwards had held several senior commands with the British forces in Palestine during the troubles there. He had served in India early in World War II. Evetts was not lacking in the rank and background needed. He had commanded Australians, those notoriously unruly troops, and unlike some British officers got on well with them. He was no stranger to arid regions either. Sometimes Evetts struck other more phlegmatic personalities as being something of a worrier. He seemed to find it hard to let things rest; to let time work out his problems for him. Yet it should be remembered how heavy his responsibilities were. With the possible exception of manufacturing an atomic bomb, his government had no greater priority than its guided weapons program. It thought the nation's survival might depend on it. Evetts had to live with the nagging sense of being engaged in a race against time. He was assisted by his clear if unsophisticated sense of what he was about. As he once told an interviewer:

> We must go all out to create—as I believe we are creating—and to maintain a team of men who will be up to test match form and capable of playing their part in the greatest Test Match of all time; namely, the prevention of war and the preservation of the unalienable rights of mankind.[14]

Of the other five members of the mission, four were also from MoS. David Clemmow (Evetts's personable right-hand man) and J. C. Yarrow represented the Munitions side of MoS, while Wing Commander R. F. Harman and Norman Coles represented the Air side. The fifth member, H. C. Calpine, a quiet and skilled radar physicist, was from the Admiralty. The various interests of the mission blended well, and together they had expertise in all the right areas—scientific, technical and military—for the unusual task of founding a rocket range.



The 1946 Evetts mission and its attached staff photographed in Melbourne

Career soldier Major General Leslie Beavis. He represented the Australian Army in the early negotiations and was chairman of a liaison committee. (AWM)

Meanwhile in Australia arrangements were going ahead to receive the mission. Much of the routine administration, of accommodation, transport and so forth, was left to two Army staff officers, one of them Major John Howard who later worked for the project in London and at Salisbury. To provide informed support the Minister for Defence set up an *ad hoc* liaising committee. This GP [Guided Projectiles] Committee had five members, representatives of the Army, Navy, RAAF, Department of Munitions and the Council for Scientific and Industrial Research (now CSIRO). The Chairman was the Army representative, Major General Leslie Beavis. Beavis was a middle- aged career soldier who had graduated from the Royal Military College Duntroon during World War I. In World War II he had served in the war as Master General of the Ordnance. This job—supplying soldiers in the field with arms and equipment—had been onerous and Beavis had handled it very competently. He was loyal and strong minded, but in speech rather inarticulate, and he had a fierce temper. One of his aides' jobs was to put a new drinking glass on his desk at regular intervals, for he used it as a gavel to punctuate his conversation. The RAAF representative was Air Commodore E. C. Wackett, brother of the famous aeronautical engineer. These two, together with Noel Brodribb from Munitions, were to take an active part later as members of the Long Range Weapons Board of Administration.

Evetts, Clemmow and Calpine arrived in Sydney on the evening of 9 April, having travelled out by Hythe flying boat. The others arrived the next day in a Lancastrian. Security was tight. There was little comfort for the waiting journalists, agog to hear the details of the mission's itinerary. The only statement forthcoming was a single sentence saying that the party was 'investigating the possibility' of setting up a test range.

On the same day (10 April 1946) that saw his team reunited, Evetts took them to Canberra for an interview with Chifley, who was on the point of leaving for London to attend the first post-war Commonwealth Prime Ministers' Conference. One very junior officer, an eyewitness to the meeting, which was also attended by Deputy Prime Minister Frank Forde, Frederick Shedden and others, recalls how warmly Chifley received the mission and how the other Ministers, very deferential to Chifley, took their cue from him.[15] Evetts formally asked permission to select a site for the Range and to make a general technical and industrial survey as his superiors had ordered him to do. Chifley readily agreed, whereupon Evetts raised some of the specific points for negotiation: the machinery for controlling the program of Range work; the attachment of scientific trainees to British defence establishments; what R&D work could be done in Australia; how the Range would be administered; and how costs were to be shared. Chifley felt these points would have to be resolved by negotiation at leisure between the two governments. One point which he did raise in detail was the question of whether, under threat of another war, Australia would have full access to the secret manufacturing information should it decide to embark on producing the latest weaponry for its own use. Evetts assured him this would be made available. However, Evetts had been told to avoid promising any contribution to the cost of producing guided weapons for Australia other than what would be needed for testing at the Range.

Lieutenant General John Evetts on reconnaissance in the Mt Eba region.

Once these diplomatic exchanges were over, Evetts turned his attention to finding a site. In consultation with the GP committee he had decided to look for one flexible enough and large enough for every possible contingency, and he already knew that what he wanted could be found forward of Mt Eba, a pastoral property west of the northern end of Lake Torrens in South Australia. It was time to exchange the map for an aerial and ground inspection of this little-known region.

Two days before Easter the mission flew to Adelaide. As their RAAF plane circled Parafield airport before landing, the Britishers caught their first sight of a sprawling and vacant munitions factory at Penfield, which their hosts were now proposing as the base establishment for the project. Obeying Chifley's injunction to 'go and see old Tom', Evetts first met Premier Playford and his Director of Lands. Their meeting was extremely cordial. Playford's ambitions for industrialising his State knew no bounds, and he was eager to secure the Range. The two men pored over a large map of the north of the State, which Evetts later remembered as consisting mostly of blank space traversed only by the faint lines of vermin fences. On Good Friday morning the mission set off again in a Dakota, with a second carrying two jeeps.

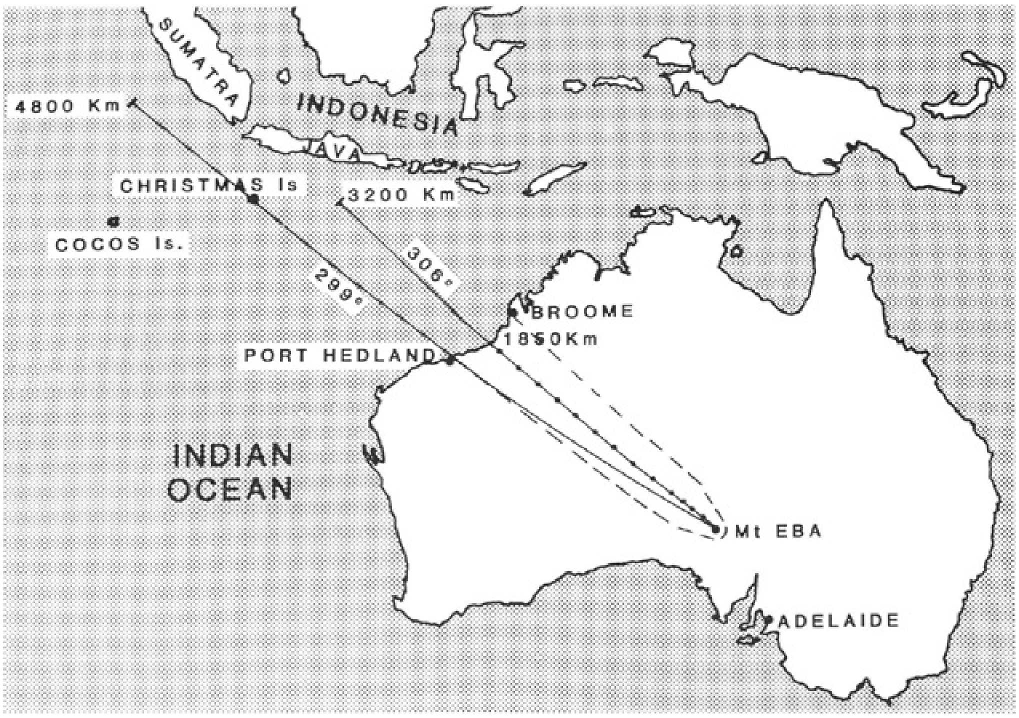
The airstrip at Mt Eba homestead was a refuelling stop for the commercial flights plying north to Darwin, and the mission happened to arrive just after the regular mail plane had departed. One passenger had disembarked. As the party began to unload its gear, this passenger exhibited a curiosity which, it soon emerged, was professional. He was a reporter from the Adelaide *Advertiser* sent up to cover the Kingoonya picnic races, and purely by chance he had stumbled on a fine scoop. Trying to retrieve the situation as best they could, Evetts, Wackett and others went into a huddle and then worked out with the lucky journalist a suitable press release. The 'secret' location of the rangehead made headline news across the country, with the newspaper illustrators drawing imaginative circles radiating outwards from Mt Eba.

The ground reconnaissance, otherwise very satisfactory, was notable for another incident. Two Australian members of the party were Air Commodore Wackett and Wing Commander George Pither, both of whom were important in the project administration later. The two men were eager to see more of the country further afield and despite Evetts's muted disapproval took a ride on the truck of a mail run north to the opal fields of Coober Pedy. On the way back the truck broke down and Wackett, Pither and the unconcerned mailman were stranded in the bush until the searching Dakota spotted them. The crew took the door off and kicked out a crate of biscuits and some bully beef, just in time to save them from dining off a parrot. Eventually they were retrieved by the manager of Mt Eba after two nights and a day next to the truck.[16]

For the rest of its very busy seven weeks the mission split up to visit various factories, universities, government laboratories and the like in Sydney, Melbourne and Adelaide. Two members flew to Perth for talks with Western Australian officials including the government geologist. Evetts himself had a formidable round of entertaining, including seven showings of a V2 film he had brought with him; and of course he was mostly responsible for writing the report. The deadline was tight, but he managed it in time and put the hurriedly finished report into the right hands in London by 21 May 1946. Almost all of its recommendations were adopted in the months ahead.

EVETTS'S RECOMMENDATIONS

The main conclusion of the Evetts mission was that the stretch of land they had selected was suitable for the project and the best available in Australia. It recommended that the Range should be constructed on a 320 kilometre-wide strip of arid and desolate country stretching 1850 kilometres north-west of Mt Eba to the coast at Eighty Mile Beach. All of this enormous slice of land was either the Crown's or held on lease from the Crown. If this length were deemed insufficient for any reason, it could be extended into the Indian Ocean for a total of 3200 kilometres or more, while still keeping clear of Java. If the firing line were swung a few degrees south (from 306 to 299 degrees true), passing now over Port Hedland and Christmas Island, a range of more than 4800 kilometres became possible. How should the Range be instrumented? The mission had no firm ideas on this, for it depended very much on the type of vehicles chosen for development. Tentatively it suggested a series of observation posts every 80 kilometres for the first 320 kilometres out from the rangehead and every 160 kilometres thereafter. Each one would be a capsule of comfortable living in the desert, permanently manned with a staff of twenty, with an underground shelter, airstrip and a fleet of vehicles.



The 1850-kilometre slice of Australian interior that Evetts recommended be used as a missile range, with its possible Indian Ocean extension.

When it spoke of support facilities at the rangehead, the mission had nothing like Woomera village in mind. What it envisaged was a base of a few hundred men, not a township of a few thousand. It thought that nearly all the work should be done at a centre somewhere close to Adelaide. The British had investigated the munitions factory at Salisbury and had been mightily impressed by its hundreds of stout brick buildings only a few years old and now practically deserted. It was ideal in every respect, and the Australians had already promised to make it available. There was no airfield at Salisbury, but at Gawler, only a short distance to the north, was something that might do: an abandoned RAAF aerodrome whose runways could easily be extended for the largest transport aircraft.

The mission had been fairly pleased with its inspection of Australia's industries, and had concluded that they could produce anything required for the experimental missiles and perhaps even take on production runs of equipment. Finding trained staff for research work was a different matter, however. A two-way flow would have to begin at once: scientists and engineers migrating from Britain and young Australian graduates going there for a year or two as trainees.

The mission's key recommendation was that the two governments should agree to establish a Range along the chosen stretch of inland Australia. For the immediate future, the planning for its establishment should start at once. British officers with executive powers should go to Australia to form a nucleus of staff there. The Australians should set up a suitable organisation, and a British team should be briefed on what was required and then sent out to work within it.

THE PARTNERS AGREE—IN PRINCIPLE

While Evetts was off finding the ideal site in Australia, Chifley was in London attending the first post-war conference of Commonwealth Prime Ministers. Here he recalled Australia's serious shortage of munitions in 1943, when supplies from Britain and the Allies had been meagre and his country had been unable to produce enough of its own to meet the Japanese threat. His government was determined to avoid a repetition in the unstable post-war world by building up its own defence industry. Australia, he said, was prepared to take more responsibility for British Commonwealth defence in the south-west Pacific area, and an expanded defence industry would be needed for this purpose as well. These remarks were preface to the tabling of the Evetts report at the informal Commonwealth Defence Science Conference held early in June 1946. After considering the report the Conference unanimously resolved that facilities should be provided as early as possible in Australia for the testing of guided projectiles and pilotless supersonic aircraft, and for the associated research and development including radio control and countermeasures.

So far neither of the governments was committed, nor could they be until a formal agreement was signed. In Britain the plan was to initiate it with a government to government cablegram. Difficulties arose, however, in getting the ministries concerned to agree on the line to be taken in the cablegram. As might be expected, the root of the dissension lay in who was to pay. The Treasury and the Dominion Office thought that each country should meet the costs incurred on its own soil: thus, Australia should be invited to pay all the capital and operating costs of the Range. The Ministry's view was that it would be politic for Britain to pay for a little more than half the operating costs in Australia, in order to retain a greater influence on the project. MoS also wanted it to start at once, if necessary on the understanding that costs would be adjusted as soon as a cost-sharing formula had been agreed. The Treasury wanted the formula settled first. Eventually the Treasury won the first point and MoS the second. The cablegram would suggest that in principle the costs should 'lie where they fall', but there should be no delay in starting work. The Cabinet having agreed to the wording, the cablegram was dispatched directly from Attlee to Chifley on 20 September 1946:

> Following for the Prime Minister from the Prime Minister.
>
> The United Kingdom Government have considered the report of Lt Gen Evetts's Mission to investigate the possibility of providing facilities in Australia for research and development work on guided missiles and supersonic pilotless aircraft.
>
> We for our part agree with the recommendation of the Mission which has since been endorsed by the informal Commonwealth Conference on Defence Science that an experimental range and supporting development establishment should be set up in Australia. We also accept the recommendation of the Mission as regards the area to be used for the range. We should be glad to learn whether the Commonwealth Government are in agreement with these two recommendations. If so, we think that the first step should be to install the necessary facilities at the rangehead and along the first 300 miles of the range and that the remainder of the range area should be reserved for future use as and when required. For this purpose we should like, if you agree, to send Evetts to Australia again accompanied by a small technical staff to collaborate with the Commonwealth authorities concerned in the detailed planning and execution of the project. Evetts would serve in a civilian capacity . . .

British Prime Minister Clement Attlee (left) at the 1949 Farnborough Air Show. (RAE)

The British offered a tentative estimate of £3 million Australian for building the rangehead and 500 kilometres of Range, including 100 kilometres of railway to join the rangehead with Kingoonya, the nearest point on the transcontinental line. They thought the Range might cost another £3 million a year to run, including the cost of the experimental firings. It is notable that the cablegram's estimate of capital cost was considerably less than the one made by Evetts, which was £6 million Australian for 1770 kilometres (1100 miles) of Range without the road and rail links.

On the question of how the expenses should be shared, the British had a proposal to make:

> Part of the expenditure on the range and development establishment in Australia will be incurred in Australia and part in the United Kingdom but we are not yet able to indicate how the total expenditure will be split geographically. We should like to suggest however that a decision should be taken in principle now that the Commonwealth and United Kingdom Governments should bear respectively that part of the expenditure in connection with this project which is incurred in Australia and the United Kingdom. If this suggestion is agreeable to your Government detailed financial arrangements can be worked out later.

Attlee, or more properly his advisers, was cautious about the virtues of the Salisbury base. He agreed that the munitions factory 'appears at first sight to be suitable for conversion' and he asked for it to be held in reserve; but he wanted more time to look at the proposal before definitely asking for it to be allocated. This caused no bother. Salisbury after all covered many square kilometres, and only a few of its hundreds of buildings would be occupied during the first tentative steps. Who could be sure that the project would grow at the predicted speed? It suited the Australians not to be committed to offering the whole factory, particularly when the Army was looking at sites for a new ordnance store.

To settle the highest questions of policy (not the executive arrangements, which would be Australia's province alone) Attlee proposed that a special joint body be established in London. This was eventually created under the name of CUKAC (the Combined United Kingdom-Australian Long Range Weapons Committee), and it continued with one or two name changes right through the project until 1980. Finally, the cablegram concluded on a note of urgency: 'I am anxious that rapid progress should be made in establishing this range which is of the highest strategic importance.'[17]

Now it was time for Australia to act. Chifley referred the matter first to his Defence Committee and then to Cabinet, which approved it on 19 November 1946.

In order to minimise interdepartmental rivalry to control the project, the Cabinet accepted the advice of Defence Minister Dedman that his department should control its policy while Munitions should be responsible for execution, on condition that representatives from Defence, Army, Navy and Air should sit on the administrative board and that servicemen should be integrated into Munitions to gain experience with guided weapons.[18] These internal arrangements having been decided, Chifley dispatched a cablegram of acceptance on 23 November 1946.[19] It was of course an agreement in principle only, and many important matters were left to be sorted out later. In particular, Chifley sidestepped the thorny question of who should pay for what. He wanted it deferred until some estimates were available—especially comparative estimates of how much was to be spent in each country. Until then he was not willing to accede to the 'costs lying where they fall' formula. Chifley also wanted to know more about the joint policy body in London; in particular, about its responsibilities. He thought that all questions of policy and facilities should be submitted formally to the Commonwealth government. The cablegram also spoke of the need for a detailed agreement, especially covering such matters as the extent of Australian participation in the work, access to information, and the financial arrangements.

In a reply cablegram[20] of 13 December 1946 Attlee welcomed the Australian agreement to his proposals, and accepted the conditions. He advised that Evetts would arrive in January to discuss the use to be made of Salisbury, and asked that the Australian views on the proposed detailed agreement be made known to Evetts. The Australians should help him draw up the financial estimates quickly so that the cost-sharing formula could be negotiated. Finally, he requested that Evetts should be able to commit up to £50 000 immediately, on the understanding that Australia would pay its share after the formula had been agreed. This would avoid delaying urgent work.

Thus it came about that Britain and Australia, after a mere twelve months of negotiation and survey, committed themselves to an enormous joint venture that was to last for more than three decades. It was a bold step, typical perhaps of the heady days of the closing stages of World War II and its immediate aftermath.

PLANS ARE LAID . . . AND THE TEAM ASSEMBLED

Many months before these diplomatic negotiations came to fruition the Ministry of Supply had started to plan the project: it had to, for there was no time to lose. A small committee which included Crow and Evetts mapped out a provisional program and described the facilities required in Australia to accomplish them. In July 1946 the committee published its deliberations in a document known as the 'Outline'.[21] The Outline looked at the projects and tried to evaluate how the Range should be developed to accommodate them. Only one of the weapons would need the full length of the Range selected by Evetts: this was the VI-like device, which had now been given the code name of Menace. The Outline described it as 'a projectile, probably a horizontal flying propulsive duct, capable of travelling 1000 miles' and thought that with the right backing a prototype might be flying in three years.[22] Within this period the Range, together with all its instrumentation, observation posts and recovery systems, had to become a working entity.

According to the Outline three other weapons would need a Range up to 500 kilometres long. One was the V2-type ballistic missile now code-named Hammer, for which elaborate test equipment would be needed at the base as well as on the Range. Another was an air-launched bombardment weapon, conceived as being a pilotless supersonic drone launched from a carrier aircraft in flight. A third was not strictly a weapon but rather a stage in the development of supersonic pilotless aircraft. The famous designer Barnes Wallis, known for several wartime aircraft designs as well for the skipping bombs used by the Dambusters, had now turned his attention to supersonic flight and was working on scale models to be flown at transonic and later at supersonic speeds. The Wallis models were to be tested in Australia by launching them from aircraft and boosting them to speed with liquid fuelled rocket motors.

Finally, the Outline proposed a separate range 32 kilometres square for high altitude bomb ballistics work. This was being done already in Britain, but it could be done a lot more easily in the excellent visibility of the outback.

Estimating that the capital cost of the Range, including buildings, services, cables, rail link, airstrips and aircraft would be £14 million sterling, the Outline ended with the warning that:

> It must be stated that there is no possibility of carrying the development of any long range projectile to a stage approaching a Staff specification within a period of the order of five years unless the programme stated in this report can be followed, and facilities and personnel provided within a period of three years. It will be clear that this will involve, amongst other things, the recruitment and training of personnel at a rate considerably in excess of anything achieved to date. On the constructional side, annual expenditure to the value of between £2.5 and 3 million will be necessitated, and preliminary talks with Australian authorities, confirming opinions obtained by Lieut General Evetts's mission whilst in Australia, have indicated that such a target is capable of achievement if the problem is tackled with firmness and as a matter of urgency.

As a serious proposal for future work into guided weaponry, the Outline was a wildly ambitious document. Britain did not develop a medium range ballistic missile until its independent deterrent Blue Streak more than a decade later, and Blue Streak was cancelled before it could be tested at Woomera. The only projects listed in the Outline that ever came to Woomera were those needing only the small bomb ballistics range or a short missile range. It was to be over ten years before the main Range was to be developed for more than 16 kilometres let alone 1600 kilometres. In fact the whole joint project was very nearly stifled at birth, as we shall see in the following chapter.

The brave sails of the Outline were soon trimmed over the following months. Its main author, Sir Alwyn Crow, left for a new post in Washington. Crow's departure coincided with, if it did not help to cause, a marked change in emphasis in Britain towards the new guided weapons. In the cooler political climate of late 1946, more than a year after VE Day, enthusiasm for the expensive kind of crash program advocated in the Outline waned within the Attlee Labour government, now preoccupied with its reconstruction and social welfare programs. It was more inclined to give weight to Tizard's opinion that weapons with a very long range were years away from realisation. Another factor was that a fresh shake-up within the Ministry of Supply was in full swing, eventually resulting in the old Air side of MoS taking over the planning of guided weapons, including the Australian project. Sir Ben Lockspeiser, formerly of the Air Ministry and later the Ministry of Aircraft Production, became Chief Scientist in the Ministry of Supply, and the Air philosophy—solve the problems of guidance, control and aerodynamics before embarking on expensive weapons systems—moved into ascendency.

Whatever the nature of the work to be done, capable men had to be found to do it. In August 1946, while the terms of the first cablegram were being debated in London, Crow and Evetts started selecting their Australian team. Evetts himself had accepted that he was the obvious choice for team leader. He had clearly made a success of the earlier mission, and he was committed.

Evetts did not pretend to have any scientific skills, and strong scientific leadership would be necessary. Britain at that time had few experts in rocket engine technology, but it did have many outstanding scientists who had contributed to the wartime development of

P. Rowe. (Topham)

radar: a field of electronic engineering which could be brought to bear on the problems of missile guidance and control. One of these was P. Rowe who had succeeded Watson-Watt as leader of the radar development team, and had been Superintendent of TRE. At the time he was Director of Scientific Research in the Admiralty. He accepted the chief scientific position in the mission, but did not last long with the project. To many of his contemporaries Rowe—the 'abominable Roweman' some called him—was stiff, humourless and obstinate; qualities which were perhaps less obtrusive in a Vice-Chancellor of Adelaide University, which he later became, than in the relatively free-wheeling atmosphere of Salisbury.

Evetts secured the services of another most capable scientist as deputy to Rowe. He was William Alan Stewart Butement, currently Assistant Director of Scientific Research at the Ministry of Supply. Rowe had originally chosen another man as deputy but he eventually declined. Time was short, and Butement was finally asked to make up his mind while on the end of a telephone line in Paris. Despite this inauspicious start, he eventually succeeded Evetts and took charge of the whole joint project. He was also to be the only member of the Evetts team to settle permanently in Australia, but then he had been born in New Zealand and had attended Scots College in Sydney for a time. He had, however, lived in Britain since the age of eleven. After completing his secondary and university education in 1928, he joined the Signals Research Establishment, a War Office outstation at Woolwich, and there, together with a colleague, P. E. Pollard, he did some pioneer work on radar. Although one of their experimental models successfully detected a sheet of galvanised iron 100 metres away, their employers were not impressed and reacted by splitting up the two young men so they would waste no more time. Since those early days Alan Butement had risen steadily in the scientific civil service. In his habits of work he approximated the vulgar stereotype of the mad scientist. His mental energy was prodigious. Mercurial and bored by administration, what he most relished was stimulating and informal society where he was free to fling off in conversation ideas by the hundred. On more sober consideration ninety-seven of these notions would be impracticable, two would be worth looking into by cooler minds (someone given such a job punned neatly that 'a think of Butey is a chore forever') and one would be a winner. He could be disconcerting. Once, during the course of a plane trip with a group of reporters from Woomera to Adelaide, someone was fingering the mesh of a luggage rack and asking what it was made of. 'A sort of plastic,' said one helpful official. 'Well,' said Butement mildly, 'it's a polyvinyl acetate, polyvinyl chloride, one of the copolymers, I think. Remarkable stuff.' He looked a little pained when someone asked him to explain, but not as pained as the official who had called it merely 'plastic'. As this story suggests, what made Butement so valuable was that his scientific interests extended far beyond his specialty of electronic engineering. His powers of lateral thinking astonished his colleagues.

Chuck Bayly, the liquid fuel rocket motor specialist of Evetts's team.

By November 1946 a team of eleven had been assembled. Fortuitously, none of them apart from Evetts had been on the previous mission. The eleven names were Evetts, Rowe, Butement, Fresson, Pye, Hunwicks, Caddy, Bayly, Wynne-Williams, Rendall and Williams. Probably they felt the parallel with the team of eleven English cricketers under Hammond who were about to play the Australians in the first post-war Test Match series, also to be held in Australia. Of their enthusiasm there could be no doubt. One anecdote describes how Chuck Bayly, ex-RAF and the only one among them who knew anything about liquid fuel rocket motors, had been given the opportunity to make his decision in an instant. A head had come round his office door one Saturday morning at Westcott and had said, 'It's the Ministry of Supply on the phone. They want to know if you would like to join the long range weapons team going to Australia?' 'Yes,' the cheerful Irishman had replied. 'When do we leave?'[23]

'When do we leave'

Evetts gathered together his eleven at Shell-Mex House on the Thames Embankment. He told them that they would henceforth be known as the Long Range Weapons Organisation, Australia, or LRWO(A). They would be going as a mission of the Ministry of Supply, and on arrival would split into two. Evetts would form a headquarters in Melbourne with Fresson, Wynne-Williams, L. S. Williams and Rendall, where they would be neighbours of the Department of Munitions and other departments concerned with the project. The other six, all of them scientific civil servants apart from Caddy, would be stationed in Adelaide under Rowe as Chief Scientific Officer. Here they would become the nucleus of the Australian scientific, engineering and support staff that would be formed around them to plan the project in detail.

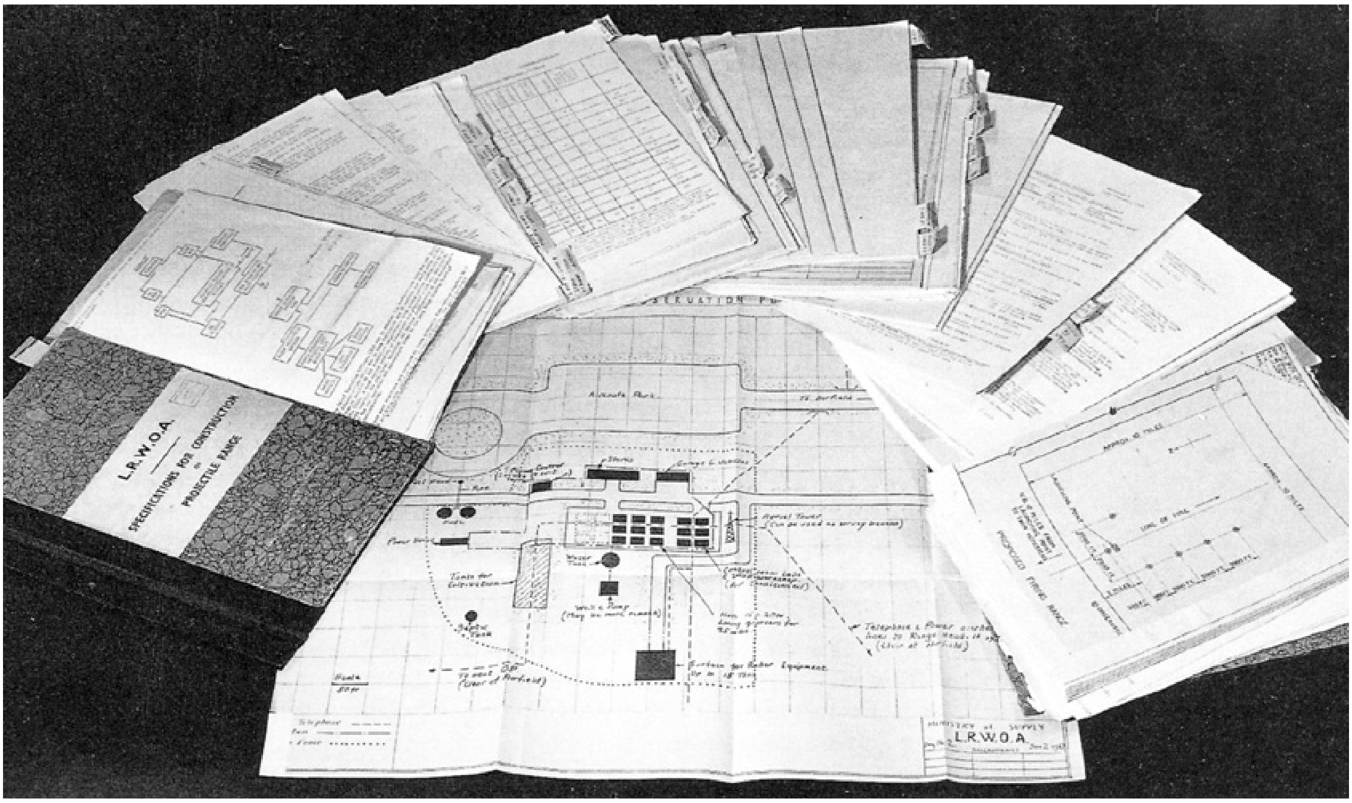
The team was soon joined by R. P. (Bob) Bonnell, also of MoS. Although not one of the original eleven, he was the first to be added to it, and like Butement he moved permanently to Australia. Bonnell was asked to stay behind in England for a year to collect information to be used in setting up the bomb ballistics range.

Many years later, Sidney Hunwicks, one of the eleven who had just missed out on the first Evetts mission because his boss had said he could not be spared, recalled his first tasks for the new organisation. Rowe had been very sick and his doctor advised him to avoid the English winter by going to Australia in advance of the main team. (This could have been diplomatically embarrassing since there was as yet no proper agreement, so Rowe entered the country as a visitor on private business.) Before going he split the likely projects between the four Principal Scientific Officer equivalents[24] and left his deputy Butement in charge. Hunwicks was one of them. He wrote:[25]

> We PSOs were to be the project's representatives in Australia, communications with UK would not be easy (air mails existed in 1946 but there was no thought of using telephones, the teleprinter link came much later and although visits by project officers were recognised as being essential at some stage, they were likely to be rare events). Therefore our task was to go to the responsible UK Establishments and Headquarter Branches and get to know their requirements in as great a depth as possible. To do this we took notes, wrote requirement papers, submitted them back to those concerned, revised them etc. etc. until both sides were satisfied. When we could we got the project teams to write the requirements and we amplified them to cover our lack of knowledge. By these means we produced a number of project plans covering the technical facilities, back-up staff and such like requirements necessary for a UK party to carry out trials some 12 000 miles from home. We would also, I am sure, have noted what was likely to be the composition of the UK team concerned, what they would bring with them or send in advance and whether these items would be transported by sea or air.
>
> Such project plans were augmented by . . . general requirements which we considered necessary—we even went as far as defining what we thought would be a multi-purpose standard laboratory bench. This we did as we expected (rightly as it turned out) to be so busy when we got to Australia that we would have not time to get together and discuss such matters. Thus over a few months we compiled a number of plans which could be used for reference both by ourselves and the project teams in UK. It was a small step to 'bind' these together into a Master Plan which for obvious reasons became the 'Bible'.[26] As far as I can recall we were very surprised that, even with delays in some projects, it turned out to be remarkably accurate and so useful.

The 'Bible' contained a revised list of weapons to be available for testing at the Range within three years. The Air side of MoS contributed to this list the projects that had already appeared in the Outline, such as bomb ballistics, high speed target aircraft and the Barnes Wallis supersonic models. However, contributions from the Munitions side had a notable omission: the long distance Menace had dropped from sight. Nothing more was heard of very long range weapons until the development of Blue Streak began a number of years later, and Blue Streak was of course a ballistic, not a cruise missile. The V2-type Hammer still appeared, with a thirty-month time scale. Several anti-aircraft weapons not mentioned in the Outline appeared in the 'Bible'. One of these was LOPGAP (Liquid Oxygen and Petrol Guided Anti-Aircraft Projectile), which subsequently became the mainstay of Woomera's early missile trials as Rocket Test Vehicle No 1 (RTV1). It is surprising in retrospect how vague the specifications for these weapons were at the time. This is brought out in a recent recollection by another of the eleven, N. H. Fresson:[27]

> While we were preparing to depart for Australia to set up the rocket range, by far the greatest problem exercising our minds was the lack of information about the weapons it would be required to test. In these circumstances it was difficult to draw up any sort of plan of



The first master plan of the Australian range was this massive document, usually known as the 'Bible'

> the range, but at the same time we could not arrive in Australia without having made any attempt to do so.
>
> Butement and I therefore went to see General Evetts and with his blessing arranged certain visits notably to TRE and Vickers with a view to ascertaining the lines on which research was progressing. My recollection of these discussions was that no attempt would be made to copy V2, and that it was more likely we would develop a winged missile, guided by automatic astro. I remember Richards of TRE outlining his views on this subject and our discussions with Barnes Wallis who, at that time was investigating supersonic flight with models . . .
>
> Having consulted the oracle we then attempted to visualise the sort of hardware that was likely to materialise and the layout of the range which would be required to test it. Distance was the basic consideration. What amounted to the first conception of a cruise missile was clearly intended to penetrate deep into Europe if not beyond. Obviously one could not build an 1100 mile range across Australia until such weapons were well advanced, so a beginning had to be made with provision for it to be stretched later. To the best of my recollection we decided to start planning observation posts up to the first 250 miles only. Planning a range based on conjecture was neither easy nor satisfactory. As one guess was built on another the results became more and more dubious and there was a tendency to doubt the usefulness of what we were doing. For those who had homes to sell and plans to make in preparation for transporting themselves and their families half way round the world (with no definite promise of accommodation the other end), the exercise tended to seem a little academic. However, we had to formulate some idea of the task we were asking the Australians to share with us and at least to show that we had done our homework so we kept at it. In the circumstances it was not surprising we were rather apologetic about our efforts and that the finished article was referred to somewhat sceptically as the 'Bible'. How useful it turned out to be is hard to say because, as factual information began to filter through so the need to consult it became less frequent until it was finally forgotten. It did at least provide a basis and ready reference when initial estimates of manpower and materials were needed and we arrived with an easier conscience for having produced it . . .
>
> I do think it worth bringing out that we were inevitably jumping the gun. We had so little information to go on but projects like that are not built in a day and the sooner we made a start the better.

Before departing for Australia, Evetts received official instructions signed by the Permanent Secretary of MoS, Sir Archibald Rowlands. They told him, in part, that he was going out as head of the Ministry of Supply Long Range Weapons Organisation, Australia, or LRWO(A), and that his task was to plan to complete 500 kilometres of the Range in the next three years. He had wide discretionary powers, but he had to be guided by the High

The remainder of the Evetts team of eleven welcomed by Brigadier Coffey on arrival in Melbourne, March 1947 left to right: Butement, Bayly, Caddy, Brigadier Coffey, Pye, Fresson, Hunwicks.

Commissioner in Canberra over all political matters if there was not time to refer to London.[28]

And so, on 14 December 1946, armed with the Instructions and the hastily prepared 'Bible', Evetts and L. S. Williams sailed for Australia on the SS *Orontes*. This steamer of 20 000 tonnes would soon be reconditioned as a liner, but for the moment *Orontes* was still unashamedly a troopship and the two men had a very uncomfortable passage. At last they arrived in Melbourne on 14 January and joined Rowe. Rendall and Wynne-Williams flew out shortly afterwards. The remainder of the eleven, Fresson, Butement, Pye, Bayly, Caddy and Hunwicks, followed two months later with their families, on the SS *Asturias*. Hunwicks many years later recalled the tiresome journey, which started in the depths of the worst winter in living memory:

> We embarked on 7 February 1947—in the middle of a very wintry period. There had been several days of snow and our car broke down about 200 yards from our local station so that we had to trudge the last part carrying our suitcases plus a variety of handbags and helping along a small boy of three and a half. Not the best of starts for a 12 000 mile journey!
>
> We sailed from Southampton at twelve noon on Saturday 8 February 1947. The SS *Asturias* was a ship of 22 000 tonnes, at the time manned and run by the Royal Mail Line for the Ministry of Transport. During the war she had been an armed merchant cruiser. After major damage due to a torpedo in 1943 she had been repaired and converted to a trooper. She was still in her trooper configuration on our trip with all accommodation doubled-up: four of us shared one cabin with our families sharing nearby cabins. Altogether there were some 1500 passengers on board including 200 children. Also included were some returning Australian servicemen and some hundreds of migrants.
>
> We took the Suez Canal route calling at Port Said, Colombo, Perth and finally arriving at Melbourne where we disembarked on the morning of Tuesday 1 March. There we were met by General Evetts.

The voyage of the eleven from Britain to Australia was more than the movement of a few people. It represented the migration of an embryonic organisation, an embryo that after a shaky start in life was to grow over the years into a very vigorous establishment. The following chapters will trace the periods of growth, maturity and old age that followed; and to tell it properly the focus of the story must shift with the eleven from Britain to Australia.

Notes and Sources

1. A fuller account is given in Brian Johnson, *The Secret War*, British Broadcasting Corporation, London, 1978.
2. This race is described from an American perspective in James McGovern, *Crossbow and Overcast*, Hutchinson, London, 1965, and there are more details in the early chapters of Tom Bower, *The Paperclip Conspiracy: the battle for the spoils and secrets of Nazi Germany*, Michael Joseph, London, 1987. Allied Supreme Headquarters did not sanction such competition, and had in fact set up a Combined Intelligence Sub-Committee (CIOS) to organise an orderly exploitation of captured German scientific data and equipment. It seems that British-US co-operation was very close at first, but deteriorated as the competition became fiercer.
3. M. Cameron, *Report on Operation* BACKFIRE, The War Office, London, January 1946. This is an official report addressed to the Commanding General of US Forces in Europe as well as to the War Office; but when one reads between the lines it is plain that Cameron had little co-operation from the US Army Ordnance officers at Nordhausen in finding usable V2s. According to McGovern, *Crossbow and Overcast*, the Americans regarded BACKFIRE as a British rather than an Allied project, and were much more interested in securing the hundred V2 rockets they wanted for firing in the US before the Russians arrived at Nordhausen. This was despite an order issued to all Allied formations on 4 May 1945, and later confirmed by the Combined Chiefs of Staff, that all V2 equipment was to be frozen until the allocation for BACKFIRE and other demands had been settled.
4. One of them was Col Sergei Korolev, the legendary 'Great Designer' of so many of the later Soviet space efforts, who through some confusion over the invitations was forced to watch BACKFIRE from outside the wire fence.
5. T. O. Lloyd, *Empire to Welfare State: English history* 1906-1976, OUP, London, 1976. There are various ways of calculating defence expenditure. These figures are derived from the tables in Malcolm Chalmers, *Paying for Defence: military spending and British decline*, Pluto Press, London, 1985. The proportions were very high by European standards. In 1962 the size of Britain's defence bill was, among its NATO partners, exceeded only by the US and Portugal.
6. Though it remained at well above 6 per cent of GDP for the rest of the 1950s. Data taken from the files of the British Institute of Public Opinion Social Survey and analysed by William P. Snyder, *The Politics of British Defence Policy*, 1945-1962, Ernest Benn, London, 1964.
7. Report, 'Future developments in weapons and methods of war', by Sir Henry Tizard's *ad hoc* committee dated 16 June 1945. PRO CAB 80/94. One may speculate that another reason for the down-playing of Tizard's conclusions may have been the release late in 1945 of the findings of a British technical mission led by Crow and sent in the wake of the advancing Allied forces to survey how the Germans had progressed with guided missiles. The mission revealed that several anti-aircraft weapons employing mid-course guidance and terminal homing systems were in an advanced stage of development; not to mention very long range multi-stage rockets. Whether these revelations weakened Tizard's conclusions even further is unknown. A revised edition of the Tizard report released in 1946 did not alter its conclusions about the future of guided weapons. Subsequently Tizard became a vehement opponent of the British independent nuclear deterrent.
8. W. H. Coulson, 'A note on the events which led to the establishment of the Woomera Range' (undated, but attached to a letter dated 12 October 1961 to J. L. Knott, Secretary of the Department of Supply). Although incomplete in one respect (it does not mention the Kearns visit at the end of 1945) Coulson's account is the most circumstantial available of the very early planning of the Range.
9. The Crow proposal is quoted from a memo dated 18 October 1945. AA MP1217 box 1910.
10. Memo dated 20 September 1946 to J. B. Chifley. AA MP1748 file GW/P/3 part L
11. Neither the author nor DOD officers have been able to find any Australian records of discussions between the government and the Kearns party about a Range, although they certainly met Chifley and other officials. A minute by Evetts dated 28 February 1946 quotes information from one of the Kearns party (Caddy) that 'a Range 1000 miles long by 200 miles wide at the target end can be obtained in Australia. A firing point could be selected somewhere to the north of Port Augusta at the head of Spencer Gulf. A line of fire in a north-westerly direction would provide a 1000 mile range with the target area in Gibson's Desert.' PRO AVIA/1506. Evetts went to Australia in April 1946 with an excellent idea of where to find what he was looking for.
12. From the Instructions for the Mission in J. F. Evetts *et al*, 'Report by the mission to Australia in connection with Guided Missiles (May 1946).'Coulson.
13. Quoted in 'Rocket chief on technical initiative', *Advertiser*, 20 June 1949.
14. Reminiscence of Brigadier E. J. H. Howard, Staff Officer to the mission, at an interview on 12 December 1983.
15. The incident is described in Lt Col E. J. H. Howard, 'The first reconnaissance for a guided weapons range in Australia', *Missile*, April/May 1954. Howard was in the searching Dakota.

16. Cablegram 316 of 20 September 1946 from the Secretary of State for Dominion Affairs, London. Shedden Papers box 1643.
17. Crow made his earlier unofficial approach direct to Coulson, possibly because he represented the Australian Department of Munitions, the nearest equivalent to his own Ministry of Supply. However, at that time research and development in armaments was controlled in Australia by the relevant service and not by Munitions. Accordingly the three Chiefs of Staff had taken a key part in the subsequent meeting with Coulson to discuss Sir Alwyn's proposal. The new project was obviously an inter-service one and could not be split up. Defence was then a small department with a policy and co-ordinating role only. CSIR declined to be involved. The solution was to give the project to Munitions but to involve the services as well. Within that department the Research and Development Division was given the responsibility for the project. This solution was to stand until that division was absorbed into the defence science and technology activities in the much larger Department of Defence.
18. Cablegram 399 of 23 November 1946 to the Secretary of State for Dominion Affairs, London.
19. Cablegram 393 of 13 December 1946 from the Secretary of State for Dominion Affairs, London.
20. Ministry of Supply, 'Outline of facilities required in connection with the Australian Guided Missile Project' (2nd edition, 29 July 1946).
21. The phrase 'horizontal flying propulsive duct' suggests a ram-jet flying bomb or cruise missile. The line of descent therefore ran from VI to Menace (which lost its top priority status in 1947, but survived as a listed item under the name Blue Menace until mid-1949) and eventually to Blue Steel (an air-launched, nuclear-tipped missile extensively tested unarmed at Woomera and in British service between 1962 and 1970).
22. Ivan Southall, W*oomera*, Angus & Robertson, Melbourne, 1962, p.31.
23. The four 'PSO equivalents' were Pye, Hunwicks, Bayly and Caddy. The first three were then graded as Principal Scientific Officer (PSO), a British staff grading also used in Australia in the early years of the project. Caddy as an Army Lieutenant Colonel occupied a post of equivalent status. Having technically qualified serving officers holding posts in civilian R&D establishments was, and is, accepted practice in the UK and Australia.
24. Contribution of S. A. Hunwicks written in 1980.
25. The 'Bible' consists of a nine page paper dated January 1947, titled 'Appreciation of the work to be carried out in constructing the Guided Missiles Range in Australia'. Bound with this are eight attached memoranda, thirteen general appendices and ten specific appendices. The copy held by DRCS library weighs 2.5 kg and bears the overall title 'LRWO(A) specifications for construction of projectile range'. However, it is understood that the document was frequently revised and that several versions exist, possibly with variant titles.
26. Reminiscence of Air Commodore N. H. Fresson DFC, written in 1980.
27. MoS document SM 2693.S dated 13 December 1945.
28. Hunwicks.

2 The project takes root in Australia

EVETTS IN CHARGE

During his uncomfortable passage to Melbourne in the European winter of 1946 Evetts had a great deal to occupy his mind. Before him lay a formidable assignment. His formal title was Head of the Ministry of Supply Mission in Australia and in the broadest terms his task was simply to plan and execute the joint project. But this bald statement of his duties concealed vast complexities. He had to oversee the creation of a rangehead on a virgin patch of arid outback, and then go on to establish the first 500 kilometres of the Range with an elaborate network of electronic and optical instruments. He had to set up a string of observation posts in even more remote and barely surveyed country, and have them manned regularly by air. He had to decide finally if the munitions factory outside Adelaide was suitable and then, at Salisbury or elsewhere, set up a technical establishment to assemble, test, repair and modify sophisticated weapons which so far were not even on the drawing board. Further down the road he had to start a training program for young Australian science graduates by having them sent to Britain to learn the latest techniques of guided weaponry. He had to do all this and more against the clock, aware all the time that his masters at home were impatient for results.

These labours were of course far beyond the powers of Evetts and the small team he was bringing with him. His official instructions were necessarily couched in general terms; so general, in fact, that the list of requirements for the rangehead ran to only four foolscap pages. It was Australians who would be doing most of the work, and Evetts had authority to hire twenty-five staff on the spot at salaries of not more than a thousand pounds a year each. Evetts's essential role was the managerial one of helping the Australians to forge an effective organisation. He was both helped and hindered by the fact that he had no clearly delineated sphere of authority in Australia, other than that granted to him by Canberra. For considering its importance the agreement between the two countries had been kept remarkably informal. Indeed, the British did not want it to be spoken of as an 'Agreement' at all. They suggested that on paper it should be no more than a Memorandum of Arrangements, which they felt better described the spirit of an undertaking between equal partners than an Agreement, which would have been registered and litigated internationally. (Despite these qualms, 'Agreement' was the only term commonly used.) Informality had its advantages, for while everything was running smoothly it meant quick decisions with minimal paperwork. All was harmonious at present, but some potential sources of friction could be foreseen.

One of them was finance. The Australians were definitely expecting to see some detailed estimates before committing themselves, and Evetts had been instructed not to get in too deeply until this had been clarified. One of the first jobs awaiting him in Melbourne was to prepare some revised estimates and help negotiate the cost-sharing terms. For the present he had carte blanche to spend up to half a million pounds of Australian money, which would allow some urgent construction work, such as the extension of the railway from Kingoonya to the construction site, to go ahead at once.[1] As it happened, work proceeded so rapidly that it far outstripped the administrative machinery. Large sums amounting to many millions of pounds were committed in both countries long before their expenditure was formally agreed to. The exact phrasing of the Memorandum of Arrangements was still being determined more than five years later, in April 1952. The American embargo on passing classified information to Australia—an embarrassing complication discussed later—had been one reason for the long delay, but another was the consideration given to the wording. For an 'Arrangement' between allies it was being examined with a doubtless necessary scrupulosity; but the effect was that by the time both governments had it before them in an agreed form, the attached financial estimates were of historical interest only. Most of the money had already been spent.

Fortunately Evetts was more than a match for his difficult job. He seemed to thrive on being in the middle. He had the easy air of authority of the British ruling class, but even the most hypersensitive of the Australians never accused him of patronising them. Though steeped in military discipline himself, he was able, unlike many professional soldiers, to adapt himself to a civilian role. Years later when he was working for a large private company, one of his former colleagues visited him and was amazed at his grasp of the personal details of every employee he mentioned.

Soon after Evetts's arrival in January 1947 the plans laid down in London began to mature. Evetts and four-of his team set up residence at the Munitions offices at 339 Swanston Street in the centre of Melbourne: the address which was to be the headquarters of the joint project in Australia throughout its most active years. Conveniently close to hand were the main offices of most government departments, few of which had then been transferred to Canberra.[2]

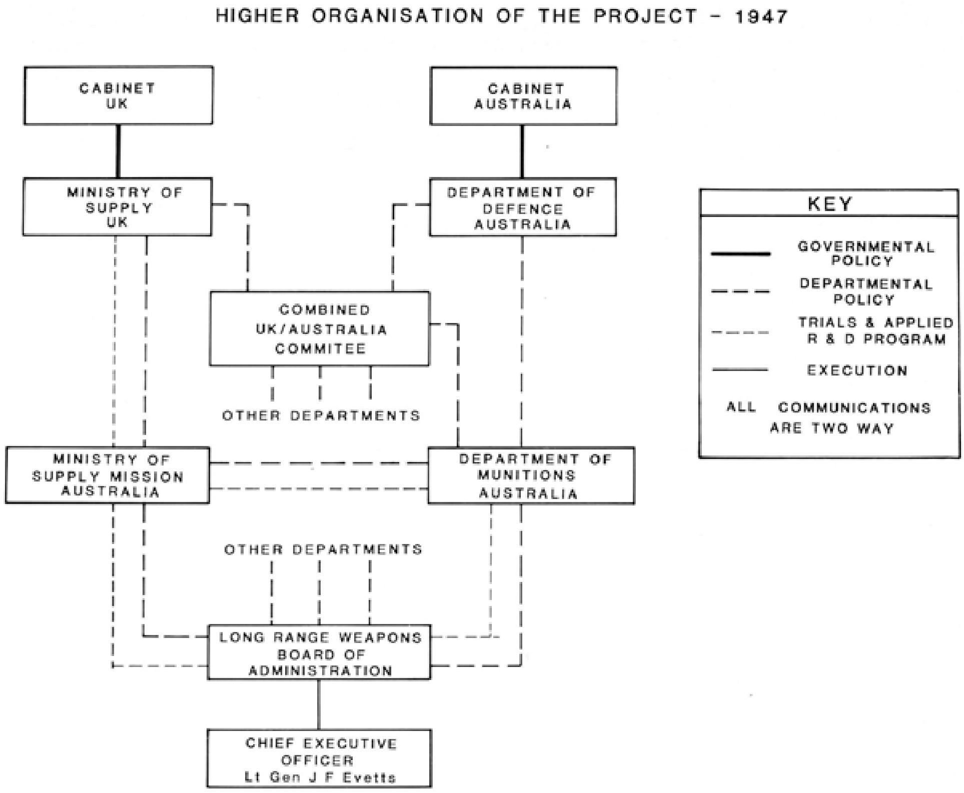
Once they had arrived in Australia the other six men of the team (all but one of them scientific civil servants) went on to Adelaide under Rowe as Chief Scientific Officer. Before moving out to Salisbury they had offices in Anchor House on North Terrace in the city. Most of them had imagined they would be acting as advisers to an existing organisation; to their surprise, they found that for the present they themselves *were* the Long Range Weapons Organisation (LRWO). However, the team had been selected for its variety of skills and had left Britain after a long round of visiting defence establishments and private firms to obtain the latest information on guided weapons. As they drew up their specifications in Australia they gradually built up a network of communications both formal and informal, so essential to a team working away from its parent organisation. Apparently the dissociation of the LRWO into so many parts—the Woomera Range was 1200 kilometres from its Melbourne headquarters—did not have the deleterious consequences one might have expected. As Butement recalls, 'it just meant you used the phone a good deal'.[3]

EARLY ADMINISTRATION OF THE PROJECT

The joint project came into formal existence on 1 April 1947, and over the succeeding years its administration became complex in the extreme. It employed thousands of personnel over several decades. In Britain, several government agencies and numbers of private firms employed as contractors had to work together. In Australia, both the federal government and a state government were involved (more than one, on occasion), as well as contractors who were either Australian or the local branches of British firms. A further complication was the large participation in Australia of the armed forces, especially in the early days: the British and Australian Army and Air Force, and the Australian Navy. As the work of the project in Australia grew more and more demanding, the administrative entities of which it was composed were constantly being broken down and reformed. It would be both difficult and unnecessary to pursue these intricacies any further than is necessary to make sense of the bodies and titles mentioned in the following pages, and so what follows is an outline.

The initial chain of command was as follows. The ultimate authority lay with the Cabinets of each country, but more immediately with the Ministry of Supply in Britain and with the departments of Defence and Munitions in Australia.[4] In Britain Supply looked after both policy and management, whereas in Australia not only did Defence have a hand in policy but the three service departments which then existed separately from Defence (Air, Army and Navy) also took a consultative role.

In Britain the most immediate responsibility for the conduct of the project was in the hands of the Combined United Kingdom-Australia Committee (CUKAC), founded in London late in 1947. It was the job of CUKAC to set the broad policy to be followed in constructing and operating Salisbury and Woomera, to consider the major projects to be undertaken, to advise on expenditures and technical matters and to report to the other organs of government in both countries. It met every three months. CUKAC was an extremely important committee in the early days because of the British view that since all major issues affecting the project had been settled government-to-government, CUKAC could handle all matters of project



The 1947 top level administration of the project under joint UK—Australian policy direction

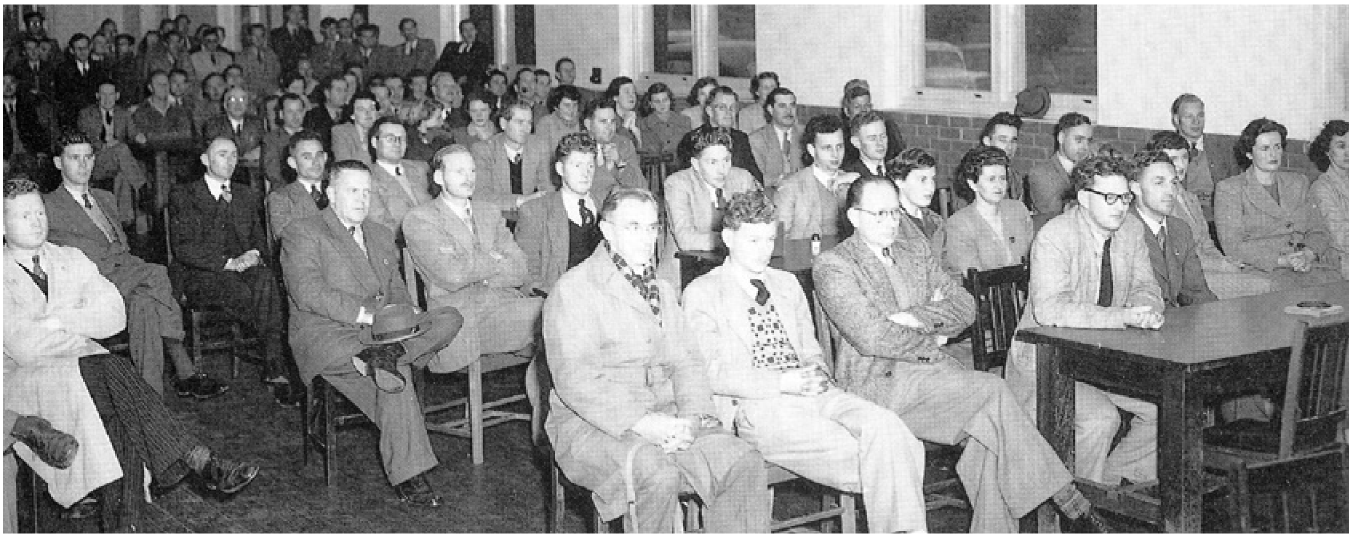
planning and finance. Thus new proposals for trials were first aired at a CUKAC meeting and put on a 'B' list if found to be suitable. The list then went to the Australian Department of Defence, and the items that were approved there went on an 'A' list. The CUKAC trials program was often revised and new editions were constantly circulating.

The formation of CUKAC in London put Australia at something of a tactical disadvantage. The British were always on their home ground when it met, and while Australia in its own interest fielded a strong team in London its most capable negotiators could not always be available. One criticism of CUKAC was that it did not restrict itself to policy but interfered in matters of administration which were for the Long Range Weapons Board to handle. As a result of this the main conduit of communication became the British Supply Staff representation in Australia, until CUKAC was replaced in 1960 by the more successful Joint Project Policy Advisory Committee (JPPAC), whose meetings were held alternately in each country.

Noel Brodribb, first chairman of the Long Range Weapons Board of Administration. (AWM)

From these various sources information and instructions fed down into the Long Range Weapons Board of Administration in Melbourne. The inaugural meeting of the Board took place on 19 February 1947, six months before it was formally constituted under the Defence (Transitional Provisions) Act of 1946. Of the ten-member Board, three were British representatives and seven were Australian. The first chairman was Noel Brodribb, Controller General of the Department of Munitions, and the deputy chairman was John Evetts. Other members of the Board were Alan Butement and L. S. Williams from the British Ministry of Supply, one man each from the Australian departments of Defence, Navy, Air, and the Army, and one from the Department of Works and Housing. It had lost its CSIR representation, since that body had refused to have anything to do with military science. Most of the Australians had been members of the old Guided Projectiles Committee formed to liaise with the first Evetts mission.

The Board's duties were broadly defined. It had to oversee all factories providing long range weapons; set up ranges and establishments in Australia to conduct research into them, and test the products. At the very first meeting, for example, which lasted more than six hours, the Board approved in principle the decision to shift the rangehead back to Pimba; Rowe reported favourably on his survey of the munitions factory, which was likely to be made over entirely to the Long Range Weapons Organisation; and surveys were ordered to provide telecommunications, railways, water and roads out at the Range site. In October 1950 the Board was replaced by a Long Range Weapons Progress and Facilities Committee



Above: LRWE staff in 1951, a time of rapid expansion.

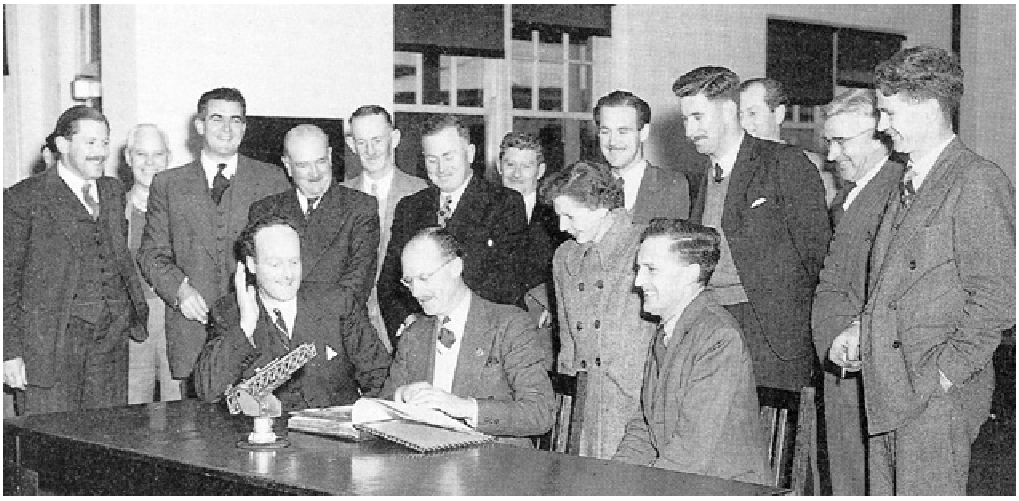
Left: R. W. Pye, who succeeded Butement (*left*) as chief of LRWE, receiving a farewell presentation from Evetts (*centre*) in 1950.

of the Board of Management, Research and Development inside Supply, but its membership and responsibilities continued much as before though the new Board of Management was now responsible for Australian-funded defence work, as well as the project.

The Board was the executive body working through a number of interlocking committees. Essentially it functioned as an agent of synthesis and amalgamation where (in theory at least) all the British and Australian points of view were resolved into unambiguous directives to be passed on to Evetts as Chief Executive Officer. Evetts in turn acted through the Chief Scientific Officer (CSO) at Salisbury. Beneath the CSO were three Superintendents, one each for Salisbury, Woomera and Mallala, which then formed separate establishments. Both Woomera and Salisbury were under services control.

To improve communications between these establishments, in October 1948 Salisbury was welded into a single unit, the Long Range Weapons Establishment, with Butement as Chief Superintendent. After Butement's promotion to Chief Scientist within the Department of Supply in April 1949, R. W. Pye and then H. C. Pritchard succeeded him. Beneath the Chief Superintendent were a number of Superintendents. 'Plans' was responsible for the overall planning of the work of the Establishment. 'Research and Development' supervised all those activities. 'Range' was responsible for all the trials apparatus at Woomera, and in addition looked after all the services and administration at the rangehead and in the village. 'Air Component' saw to the maintenance and operation of the air transport system, and to the conduct of any air trials held other than at Woomera. Further down the ladder again Principal Officers were in charge of the main sections of the large Salisbury bureaucracy: general administration, trials co-ordination, construction plans, personnel, accounts, and all the rest. This staff underwent rapid expansion in the first few years, with the appointment of officers to look after administration, stores, workshops, transport and so on. Once the immediate program was set—parachute trials, bomb ballistic trials, VT fuzes, tests of rocket test vehicles such as LOPGAP, and further away the target aircraft development and trials of guided weapons to be sent from Britain—the professional staff grew rapidly. Scientific staff, or equivalent non-scientific staff (excluding clerks, laboratory assistants, draughtsmen and industrial grades) totalled forty-two in July 1948, eighty-five a year later, and 220 by July 1952.

After visiting England in October 1949 Evetts surrendered his post of Chief Executive Officer of the Board, in order to remove the impression that the British were controlling the project in Australia. He continued to be head of the Ministry of Supply Staff (UKMOSS) which was located in part of the same office space at Swanston Street allotted to the project. He returned home for good in 1951 when he reached the age of sixty, and was succeeded as head of UKMOSS by Ivor Bowen.



Farewell to Evetts before his return to the UK in 1951. Seated at the right is H. C. Pritchard, Pye's successor

THE CANCELLATION 'CRISIS'

Towards the end of 1947 a problem arose with the new project which in one view threatened to halt it before it had well begun. Alan Butement, then second in command to Evetts, has written a circumstantial account of what he calls a 'crisis' in its affairs:

> About one year after the mission arrived in Australia, and preliminary plans had been made to develop a rocket range for the specific requirements of the Ministry of Supply as had been stated when the mission left England, a crisis arose. It appeared that the Ministry had revised its plans, and that a rocket range was not required, or at least not for some years. As the Australian Government had already spent or committed considerable sums of money, this was, from the point of view of that Government, highly unsatisfactory. As a result, Evetts and II returned at short notice to the UK to discuss the matter. On arrival, talks took place with officials of the Ministry of Supply, and it became clear that so far as that Ministry was concerned the Range could no longer be supported. A discussion then took place with Sir Henry Tizard, who was then Chief Scientific Adviser to the UK Defence Ministry, and he advised the continuance of the Range plans, but on the basis that the Range should be developed to accommodate any kind of guided weapons trial, and not a few specific items, as had been the basis of the earlier planning, it was to be developed as a general purpose range and as Tizard put it 'the range will attract work as a magnet attracts iron filings'.[5]

Sir Henry Tizard (*right*) visiting Farnborough. (RAE)

This account suggests that the very survival of Woomera was in question, until it was saved by Tizard's decisive and almost clairvoyant judgment. At any rate, there was every reason for Evetts, a man of action, to hasten to London to find out what was going on. According to Butement's account, Evetts's party arrived there to be greeted with the news from Sir Ben Lockspeiser, Chief Scientist of MoS, that, 'the long-range weapons project was finished'. It is doubtful if Lockspeiser ever said this so bluntly, although privately he may have favoured the indefinite deferment of the Range.[6] Even if it was quite untrue, a rumour abroad in Australia that the British were growing lukewarm about the Range could have had incalculable consequences.

What *was* the actual position in British defence circles during the second half of 1947? As we saw earlier, Evetts had gone to Australia at the beginning of the year with instructions to establish 500 kilometres of Range within three years. He had gone armed with the 'Bible' listing the projected weapons and the facilities needed for them. Of these, only two required the full distance. These were the air-launched Barnes Wallis models for investigating supersonic flight, and Hammer, the ballistic missile to be developed from the V2 and thus sometimes referred to as the 'super V2'. The others were bomb ballistics work, parachute trials and the like which were to be carried out on a separate area; and testing of experimental guided missiles such as LOPGAP for which 80 kilometres of Range would be more than adequate. By the middle of 1947 at the latest the British had concluded that ballistic missiles were best left to the Americans for the time being, on the grounds that their guidance problems were likely to be too intractable for them to tackle alone. In any case, they had failed to secure much of the war booty of V2 hardware and documents which were removed in some haste to New Mexico. They had also lost key scientists like von Braun to the Americans. The cancellation of Hammer meant that the objective, always optimistic, of '300 miles in three years' now rested solely on the Wallis models. The 1600 kilometre Menace which had figured so prominently in the Outline of July 1946 found no mention at all in the 'Bible', because by then it had been accepted that it could not possibly be produced in three years.

On the other hand, the Attlee government naturally could not ignore the deepening frost of the cold war. The Soviet Union was building a large force of fast high altitude bombers, and the atomic bomb was almost within its grasp. The nuclear armed bombers could be opposed only by supersonic interceptors, whether in the shape of fighter planes or accurate ground-to-air missiles. It should be borne in mind that it was uncertain at this time whether a manned supersonic fighter could be deployed reliably. The sound barrier was broken during a test flight over California in October 1947, a feat not repeated in Britain until a year later.

In June 1947 the Defence Research Policy Committee met with Tizard in the chair and, after considering a paper by Lockspeiser summarising all the current weapons and problems, revised its priority list. Given an 'A' priority for development were several short range guided weapons: the air-to-air Red Hawk (which led to Blue Sky and Blue Jay) to replace or supplement the guns on fighter planes; the ground-to-air Heathen (later more familiar as Bloodhound and Thunderbird) to replace antiaircraft gunnery; one ship-to-air missile (Seaslug) to replace ship armaments; and finally the controlled bomb Blue Boar. The bombardment drone continued as priority 'B'.[7] For all these projects Woomera was no less indispensable than if a long range ballistic missile was still being pursued, for the British ranges were inadequate even for the trials of these projected weapons. But this was not the rationale which had sold the Range to the Australians.

These changes of direction, accompanied by some official heart-searching and vacillation, did not go unremarked in Melbourne. As early as 30 May 1947, when he had been in his post only a few months, Evetts was already being worried by certain semi-official intimations coming from Ministry men. They spoke in guarded tones, but what they seemed to be telling him was that with the cancellation of Hammer a general deceleration in the planned guided weapons work for Woomera was definitely on the cards. These hints certainly did not square with official policy, which on the surface was continuing unchanged. In fact exactly the opposite emphasis seemed to be given in a cablegram which passed directly from Attlee to Chifley, stressing the value of co-operation in Commonwealth defence. 'Our experts', Attlee was saying, 'would like to discuss with yours as soon as possible an accelerated programme for the development of Guided and Air Launched Weapons'.[8] Here were some puzzling contradictions. Could it be a case of one hand of government not knowing what the other was doing? Neither Evetts nor his Australian advisers, far removed from the internecine struggle—if that is what it was—were quite sure what this indecision presaged. They agreed to do nothing for the time being, except for the prudent step of postponing very large commitments like buying transport aircraft, until they had had a chance to discuss it face to face with the man most likely to know what was going on: George Gardner, Director of Guided Weapons (Research and Development) at MoS, who was due to visit Australia in July. Gardner did pay his visit, and he did not bring any surprises with him. He assured the Board that the 'original phasing' was still needed, and indeed that efforts should be made 'to improve if possible on this timetable to allow techniques to be developed for trials and to give personnel an opportunity of becoming familiar with launching drill'.[9] The bomb ballistics and parachute trials work would go ahead immediately, and the launching site which had been intended for Hammer would now be used for short range missiles such as LOPGAP. With that assurance, the Board continued to press ahead full bore, for example by authorising expeditions to fix the sites of the observation posts far out in the desert along the northern flank of the Range.

Nevertheless, despite Gardner's assurances, more hints continued to surface that the British were reassessing their priorities. In October 1947 the second meeting of CUKAC in London discussed the first issue of the trials forecast—a revised version of the program sent to Evetts the previous May. This forecast showed that the target date for the Australian trials of the Wallis high speed models had moved back. It had now been decided to test the twenty-four first-stage slower models in the Scilly Isles, perhaps because Wallis was reluctant to accept the delay in having his trials done on the other side of the world. It was not certain that even the later trials would be done in Australia, but if they were then the earliest starting date would be December 1950, not December 1948. The significance of this slippage is that these trials were now the only project remaining which required 500 kilometres of Range, and the imminence of these trials had been the cause of the pressure on the Organisation to complete the string of observation posts out to this distance. This announcement of a two-year postponement at best, and at worst yet another cancellation, caused the Australian representative at the meeting to observe pointedly that his government was devoting very great resources to the project. It could not allow the build-up of facilities in Australia to move too far out of step with British plans.

Worse was to come. On 6 November 1947, Evetts attended the Board's sixteenth session as its acting chairman. All was tranquil then, but the storm broke some time over the next week. Almost four decades later Evetts described what happened:

Sir Archibald Rowlands, permanent secretary of the Ministry of Supply. (Topham)

> One morning Sir Fred Shedden rang me up to ask me if I had received a communication from the MoS which stated quite bluntly that the British Government had given up the development of the V2 [i.e. Hammer, the ballistic missile] which was to be handed over to the USA and developed by them. He, Shedden, was in an angry mood as he explained that this decision had been sent to the Australian Government over the signature of a Flight Lieutenant of the RAF! I replied that I entirely agreed with him and that I too had received a similar document. I also was not only amazed but angry as well at this extraordinary way to handle such an important matter of policy by the MoS. I told Shedden that I had decided to go to the UK at an early opportunity to point out to the MoS the harm that had been done not only to our (British) relationship with the Australian Government, but also to the projected programme . . . So I set off with Butement by flying boat to London where I went with Butement straight to the office of Sir Archibald Rowlands who was the virtual head of the MoS. (You may appreciate that I had known him for some years and we were on very friendly terms.) After I had put our joint Australian-British case to him, he said he was going away for three weeks and suggested that Butement and I should spend our time working out a new programme to replace the present one which had been seriously damaged by the decision to move the [post-V2 development] to the USA. This we did to the best of our ability, helped now and then by some friends I had in MoS. On Rowlands' return he quickly summoned a meeting of all the heads of MoS, where he explained the seriousness of the situation and the steps which should be taken to satisfy the Australian Government and at the same time produce an entirely new programme for Woomera and the range-to-be.
>
> After the meeting Rowlands took me aside and told me he relied on me to put right what had been a bad mistake on the part of MoS.[10]

We see here that Sir John, understandably after such a great lapse of time, has rather telescoped the flow of events. It could not have been the Hammer cancellation which triggered off his urgent visit, for that had certainly occurred in the middle of the year or earlier. However, the rest of his recollection is correct. Doubtless he had been appalled to receive a single page letter from one A. J. (Tommy) Handley of MoS in London, a Wing Commander of almost legendary insouciance. Handley informed him quite nonchalantly that for the next five (not three) year period the Range would need to be instrumented only over 80 kilometres with an additional 420 kilometres as a danger area. Handley offered no advice on how this unwelcome news was to be passed to the hard-pressed Australians.

Here certainly was a crisis of confidence which had to be resolved before the hitherto smooth negotiations over the use of the Range were disrupted. Evetts wasted no time. Pausing only to cable Brodribb, the chairman of the Board who was then visiting London, he scooped up Butement and his administrative officer, L. S. Williams, and left post-haste for England on 23 November 1947.

Fortunately not only Brodribb but also another Board member, Major General Beavis, was coincidentally in London, and the latter represented the Defence Department at the four meetings where the implications of the British decision were thoroughly discussed. Possibly the most important was the third CUKAC meeting of 3 December 1947, attended by Beavis, Brodribb, Butement, Evetts, Gardner and Williams, and chaired by Lockspeiser. Here once again the '300 miles in three years' policy was confirmed, though now with the significant rider that 'fluctuations in and changes of programme such as had recently occurred were not to be regarded as countermanding those instructions'.[11]

This, then, was the message Evetts brought back to the Board of Administration. Essentially it was the reassuring one that the British government still regarded the joint project as having the highest importance. Certainly it could not be denied that the term 'fluctuations' was a euphemism for the abandonment of trials along the full length of the Range, for what turned out to be more than a decade. Priorities had certainly shifted. Now the first was to prepare the bomb ballistics range, and the second was to build a range suitable for flying the LOPGAP test vehicle, vertical take-off aircraft and ground-launched transonic models. Extending the Range out to 500 kilometres had fallen to third place in the order of priorities, and over the next few years it slipped quietly from view altogether, along with the Wallis model trials of which nothing more was heard. They had vanished from the second issue of the trials forecast released in August 1948. On the other hand, the immediate consequences were small: at Salisbury the growth of staff was not quite so rapid as anticipated, and the static test beds and tower for Hammer were never built.

Though fears that the joint project would be scrapped were quickly laid to rest (if they had ever been widely entertained at all), grumblings about the new priorities did continue for another year or so as it became more obvious that the trials were taking no advantage of Woomera's unique location. Bomb ballistics, and the minor proximity fuze and parachute trials, could have been done anywhere in the drier regions of Australia without the expensive infrastructure of Woomera and Salisbury. The services representatives on the Board became restive again: how much was this work really contributing to Australian defence needs? When were the big, glamorous projects going to be announced, something commensurate with the great labour and the millions of pounds being expended in South Australia? The Army spokesman feared that the original conception of Woomera was being lost sight of. The use of the Range for so many small tasks engendered the suspicion that 'busy work' was being supplied to keep Woomera alive and the Australians happy. On that occasion the Board agreed to have an expression of apprehension transmitted via Evetts. In their response[12], the British counselled patience. They well knew that a major project would give 'great satisfaction' in Australia. It was true that no project was in hand for a long range weapon, but in the distance did lie the prospect of a long range bombardment drone. Its exact specifications were undecided, but apparently what was in mind was some extension of the Jindivik target aircraft project, to produce a supersonic expendable bomber weighing 50 tonnes or more, presumably armed with an atomic bomb. (No ballistic missile of the day could carry a weighty nuclear payload.) The United States was already experimenting with converted pilotless bombers, and in 1947 a Skymaster made an automatically piloted flight of 3860 kilometres across the Atlantic. It still did not seem impossible that a British version might be gliding down the full length of the Range and out over the Indian Ocean in about five years' time. But the key problem with any long range bombardment drone was that of terminal guidance: bringing the vehicle accurately over its target before the bomb was released. Only at Woomera could the final trials of such a system be undertaken. The Ministry asked the Australians to bear in mind that in Britain even the longest sea range was only 50 kilometres long. The longest land range in the country stretched a mere 1 kilometres, when the runway alone of an expendable bomber might need to be 8 kilometres long. Woomera's day would come! The present work, such as that on bomb ballistics, might seem rather small beer, but it was giving experience in radar and optical measurement and in computation methods. The best plan was for the Australians to go on building up a solid organisation and a wide-ranging R&D program, against the day when a large project could be started.[13]

There is no reason to doubt that the British were sincere in these sentiments. Once the waverings of early 1948 were over, they behaved as though Woomera was an irreplaceable facility which they did not intend to abandon. The Australian government was still a little jittery, though; especially when it discovered the following year that the British were negotiating an agreement with the US to set up on British sovereign territory what became the Atlantic Underwater Test and Evaluation Centre off the Bahamas. Only after Canberra applied pressure were full details provided, but they did come with the further assurance that plans for Woomera were in no way affected. Evetts again went to London in June 1949 and again brought back confirmation that there had been 'no diminution whatsoever of the interest of the United Kingdom in the Long Range Weapons Project'. No one, said Evetts, need have any doubts 'about the wisdom of the overall plans which we of the [Board] have been responsible for sponsoring'.[14]

Both sides had learnt something from the cancellation scare which stood them in good stead later: the Australians saw the need for patience and the British the value of frankness in admitting to changed plans. Everyone now recognised and accepted that the provision of facilities in Australia could not hope to march exactly in step with the British development program, because much of what had to be provided, especially at Woomera, had to be built whether the rangehead and village were going to have in front of them 50 or 500 kilometres of Range. In the long term the virtue would be apparent of siting the rangehead in a place where a very long extension could be added without wasting any of the capital assets. These were the most important lessons of the cancellation threat.

PRIORITIES ARE RESET

One of the temporary effects of the uncertainty had been to hold up the final seal of the Australian Cabinet's approval for the project's absolute national priority. In December 1947, while matters were being sorted out in London, Chifley told the Munitions Minister, John Armstrong, that the Defence Committee wanted to hear Beavis's opinion on 'the latest intentions regarding the development of Long Range Weapons' before settling the question of priority allocations—of both materials and men—to the project.[15]

Once he was back in Melbourne with the clarification he wished for, Evetts pushed hard over the next months for the priority question to be settled finally. He was very firm that, once taken, the decision should be understood right down the line. He expressed himself in no uncertain terms to Eric Cook, Secretary of the Board:

> If the project is treated as being of the highest priority, as requested by the UK, the controlling authorities should be able to take exceptional measures without fearing repercussions from rival activities of lesser importance . . . The crux of the matter is non-availability of men and materials in South Australia. To overcome the shortages it is clear that exceptional steps must be taken and these require the full backing of the Federal Government and of the State Governments. This backing can only be made effective by specific instructions right down to the lowest level of all Federal and State authorities in any way concerned,[16]

As a result of Evetts's representations and their own sense of its urgency, the Defence Committee recommended, and the Cabinet approved, giving the joint project total precedence over all other works of the Commonwealth and the States alike, not excluding other plans for the armed forces. The project took first place in the queue for all allocations of materials. The Commonwealth already had control under the Essential Materials Order of steel, timber, galvanised iron and cement and there was no difficulty in, for example, reducing export licences so as to divert one million super feet of jarrah from Western Australia to Woomera. As for personnel, the forces had already agreed to give top priority to allocating servicemen to the Range. The government had lost the power it had had during the war to direct labour, but the Public Service Board was ordered to transfer all the staff required from other departments, whatever the inconvenience.

In October 1950 with the Korean war four months old the British raised the priority of guided weapons research again. In that country it was now given a special priority which it shared only with 'atomic energy', that is, with the all-British atomic bomb. Effectively it meant that nothing was allowed to stand in the way of realising the development of weaponry. Money was no object. Shortages of resources and manpower were shrugged aside, and all the contractors engaged on guided weapons were prodded for ideas on how to accelerate their work. Evetts followed through by asking for an assurance of equal priority from the Australians. This put the Australians into something of a quandary. For all intents and purposes the joint project *was* the nation's military research and development effort. Compared to the British efforts relatively little was being done elsewhere in defence science, so the project was absorbing much the greater part of the allocated resources. The

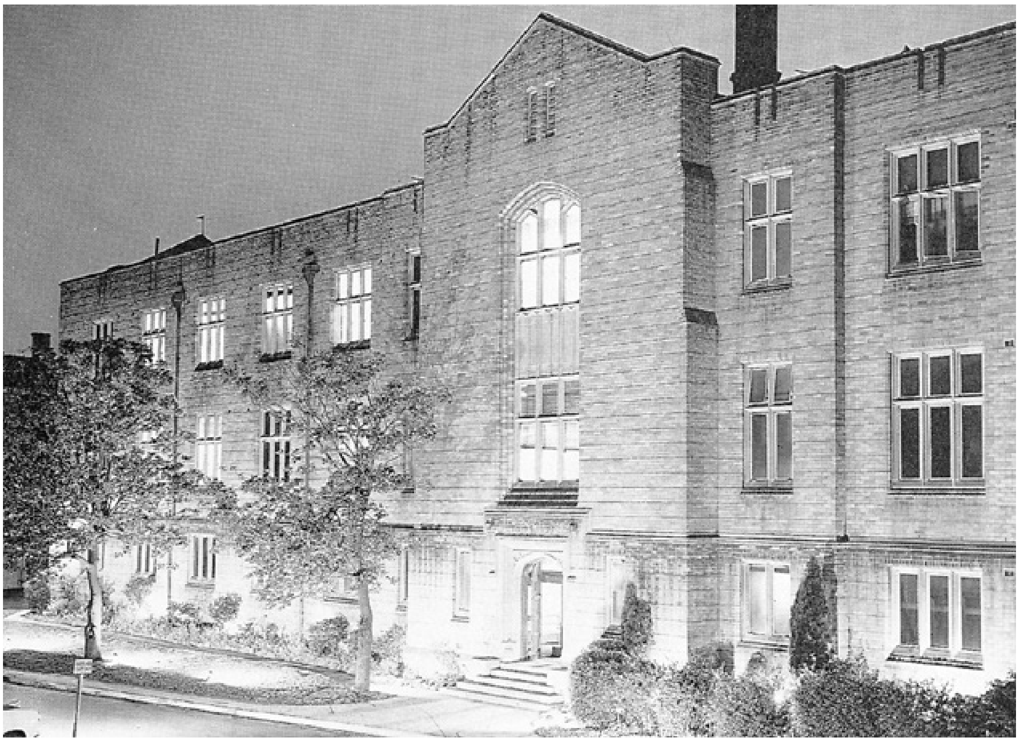
Australians therefore felt with some justice that they were already giving at least as high a priority to the project as Britain was; but it was not, for all that, an absolute priority. Officially it shared top priority with domestic housing, but in practice just as much construction effort was flowing into the facilities for conscription and hostels for the flood of post-war migrants. In addition, the all-Australian military research work outside the project, started with British concurrence, was beginning to take up more resources.[17] After some cautious consideration the final response was that 'the guided weapon programme, and in particular the Joint United Kingdom/Australian project will continue to receive the highest priority in the Australian research and development programme'. The priority of R&D itself, however, was left undefined—an adroit move.[18]

SECURING THE FIRST SCIENTIFIC STAFF, 1947-50

Sir David Rivett, chairman of CSIR. (CSIRO)

In May 1946, while the Evetts mission was going about its business and the Australians were beginning to take the Range plans seriously, a memorable meeting took place in Melbourne. The meeting was in fact more of a confrontation; it might even be described as a showdown. On one side were Sir David Rivett, the austere and utterly dedicated chairman of the Council for Scientific and Industrial Research, with two of his high officials. On the other were Brodribb and Beavis, representing Munitions and the Army respectively. The purpose of this uncomfortable meeting was to ascertain to what extent the talents of the CSIR could be drawn on for the benefit of the project. Rivett's position was uncompromising. The resources of the Radiophysics Laboratory at Sydney University would not be available for guided weapons work. Indeed, he told them flatly that CSIR would be undertaking no military work of any kind.

This was a very severe blow, because practically all the talented people Australia then possessed in the fields of electronic guidance, tracking and control were engaged on radar work and were associated with the Laboratory. Not to have them at the disposal of the project would mean building a whole research force from scratch. But Rivett was obdurate. He knew well that CSIR scientists had given their all to radar in the war, sacrificing their own ambitions to the common good. Enough was enough. Now it was time for the community to let them catch up on their fundamental researches, especially in the emerging and fascinating field of radioastronomy. They were going to be very busy, he said; but if they did have any time over, they would devote it to work on navigational aids and other peaceful projects.



The Radiophysics Laboratory at Sydney University. (CSIRO)

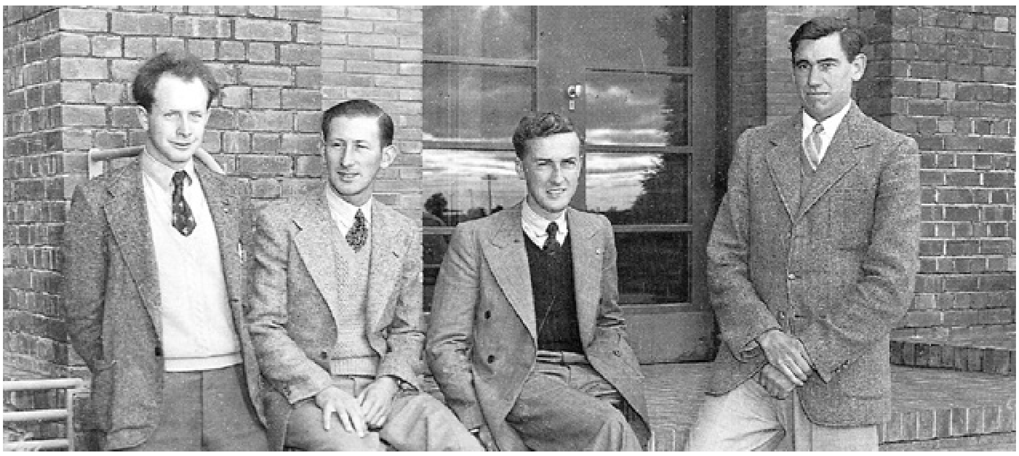
When someone (probably Beavis) blustered that the future use of the Radiophysics Laboratory was a matter of government policy and not in Rivett's hands, Rivett replied icily that the independence of CSIR had been guaranteed by charter when it was founded in 1926. And that was that. Many eminent scientists were on Rivett's side. Later, in May 1948, Professor Mark Oliphant wrote from England applauding his stance, asking with typical vigour 'would it not be wise to transfer all secret work and contacts with secrecy from CSIR to the Supply Department and force them to set up a scientific organisation of their own. They could revel in red stamps and stultifying work to their heart's content and CSIR could be free!'[19] Apart from the arguable stultification, this is just what happened. Although moves in 1948-49 to bring the CSIR under the control of the Public Service Board filled some scientists with trepidation, the history of CSIRO and Australian military science proceeded afterwards along separate lines.

There was nothing for it, then. The Organisation needed urgently to recruit a nucleus of engineers and scientists and train them from scratch; and to this end advertisements were placed in both the Australian and British press. At first it was feared that rather few applicants might be interested in project work because of the necessary secrecy and the denial of publishing rights, but in the event more than 300 people applied to the first advertisements for trainees, even though the salaries being offered were hardly princely: the top post was worth only about a thousand pounds a year.[20] The successful candidates were without exception of British or Australian stock. The many applications from 'persons of foreign origin and Aliens not long resident in this country' were automatically rejected by the Chief Scientific Officer, who 'adopted the attitude of giving preference to British Empire applicants even though their qualifications may not be of such a high standard as the others'.[21]

Many of the new trainees were selected from among Australia's first crop of post-war science graduates. These fresh young physicists, mathematicians and engineers (and their teachers) saw a rosy future ahead. Existing research bodies and university departments had gone through lean times during the war. Now with the onset of the joint project and the predicted consumer boom came the promise of many opportunities. Kerr Grant, Professor of Physics at the University of Adelaide, was not slow to suggest in July 1946, before anything had been made public of the Evetts mission's deliberations, that if scientists were going to be employed on defence research there was no reason why a good proportion of them shouldn't be Australians, since the University was stocked with men 'whose competence was not, on the average, inferior to that of their colleagues overseas'.[22] Those reluctant to consider purely military work could, he said, comfort themselves with the thought that important public benefits had emerged from the pressure cooker of wartime research. This was undoubtedly true, although Professor Kerr Grant's example of the fruits of such research—the pesticide DDT—now seems an unfortunate one.

In fact Kerr Grant was slightly off target. The problem was not the intellectual calibre of the graduates, but the lack of resources to give them the specialised training they needed. Their undergraduate courses in physics, in electrical or mechanical engineering, had not had a great deal to say about the recondite arts of guided weaponry. Evetts's recommendation that some of the trainees should be sent for paid postgraduate training in Britain was therefore quickly taken up. The knowledge that 'several' of those selected would be sent for

A group of young trainees and other scientific staff at Salisbury in 1949



training there for periods ranging up to two years itself guaranteed plenty of applications from the cleverest graduates. The opportunity for research in what many still thought of as the mother country was a prize very well worth having in those more straitened days. More got the chance than the initial announcement implied, for by September 1947 the total number of trainees approved to go to Britain (not all of whom were to be employed on joint project work) was forty-four. The first man, Kevin Boyle, left for the Orfordness Research Station on the East Anglian coast on 3 December 1947 and three others had joined him there by mid-January 1948. By April of that year twenty-five more names had been selected to undertake a two-year period of training on the job in aeronautics, electronics and physics at important defence establishments. All of them were men. Women were never seriously considered for the trainee scheme. Their applications were blocked, according to rumour, by a very highly placed officer whose habit was to scrawl 'no women!' over their forms. Sidney Hunwicks recalls the fate of one woman in more detail:

Kevin Boyle, the first of over 200 scientific trainees, was sent to the UK in late 1947.

> Among those applying for trainee positions was one girl—at that time it seemed exceptional for girls in Australia to take science degrees. As she had all the necessary qualifications I shortlisted her for interview. To my surprise some members of the Department regarded her candidature as unacceptable and asked: 'What would the UK think if we sent them a girl?' When I said they would accept her without comment as there were lots of women scientific officers in the UK, I was hardly believed. After a lot of argument I was told the interview could go ahead but without prejudice to a final decision being referred to the highest level. In the event she did not get through the interview and so the argument was left unresolved.

The men who succeeded in getting a traineeship were being given a good opportunity, but it was by no means a sinecure. They were not treated with any great generosity, and they had to sign a bond undertaking to continue with defence work for three years after returning to Australia. Off these young men went by ship and plane, their bodies well padded against the bracing climate with heavy coats bought with a £40 outfit allowance which the government kindly supplied. They found post-war Britain an austere place indeed. Practically everything was rationed, and even though their pay was very high by local standards (one man found only the Director of his establishment was paid more than he) there was not much to buy; in particular, very little inviting food was to be had. Few of the trainees cared that much about food, but several still recall with a shudder 'soup' of several varieties all made out of curry powder, cornflower and water, powdered 'scrambled egg' and bread rolls that collapsed into dust when bitten into. They recall too their constant craving for sugar and tobacco, and how eagerly they anticipated the food hampers from home. One man went to Cambridge but found it a cold and depressing place. Though he lived in the romantic Grantchester he was chiefly struck by the long tenements of grimy brick, the icy wind ripping across the Fens, and the gloomy streets, gaslit in winter by four in the afternoon. He and his wife were pleased to discover in the Botanic Gardens a single eucalypt, struggling to survive in a heated greenhouse. But these were only vague impressions. He was too busy studying electromagnetic theory for 90 hours a week to notice much else.

The trainee scheme was very successful, and once underway provided a useful flow of talent back to Australia. By 1950 eighteen trainees had completed their two-year training periods and had returned; a second group of thirty-four was completing its first year; and the recruitment of the third group was going ahead. Some hiccoughs were caused by the American embargo of 1948-49 on passing classified information to Australia; but (as will be described in Chapter 7) the problems were alleviated when Butement and Sir Ben Lockspeiser hit on the plan of putting the embargoed batch of trainees into suitable British universities as graduate students. Generally the ones that had this extra opportunity used it to the full. Soon after he arrived at Cambridge one student, Bob Edgar, was handed his professor's newly published book on antenna design, and disconcerted him by finding a string of mathematical errors in the opening pages. Edgar, who spent the rest of his career in the Radio Group at Salisbury, went on to take a First in the Mechanical Sciences tripos at Emmanuel College after a single year's study.[23] Edgar's determination was typical of the trainees, many of whom eventually occupied high positions in academia, industry and the scientific branches of government. The trainee scheme did indeed fulfil its purpose of providing the first generation of Australian scientists trained in the new disciplines, but by the end of 1954 it had merged into the other new Commonwealth schemes whereby talented students could take their higher degrees at one of the great institutes for graduate study overseas.

FOOTING THE BILL 1: THE DALTON FORMULA AND THE SANDYS AGREEMENT

To bring this chapter to a close it is necessary to say more about the shared financing of the Woomera project in Australia. It hardly needs stressing that when two governments half a world apart decided to set up a rocket range in outback South Australia and a support centre outside Adelaide, they were considering the expenditure of vast sums of public money. Nothing on the scale of the joint project had been seen in Australia during peacetime except perhaps the Snowy Mountains hydro-electric scheme. Though the '300 miles in three years' objective died after a year or two, this did not reduce the size of the project or cut its costs appreciably. So much had to be done anyway: starting up the technical establishment at Salisbury; building the village and support area at the rangehead (Woomera); setting up a range for bomb ballistic, fuze and parachute trials; and getting into operation an air transport unit. The RAAF ran this from Mallala at first, but later it transferred to the new Edinburgh Airfield next to Salisbury.

When the Range proposal was first aired in 1946, the British advised the Australian government that the immediate cost of setting up the joint project facilities would be £3 million; plus, eventually, another £3 million a year running costs. When more detailed estimates came to hand, they showed a planned expenditure by the Australians of £26 405 000 in the five years from 1 July 1947 to 30 June 1952; and by the British of £23 206 000 sterling from 1 March 1947 to 31 March 1952.

The Australian estimates were laid down in great detail, mostly in the form of itemised building estimates from the Department of Works for developing the Range infrastructure. The British estimates, by contrast, were provided in the most general terms. For instance, they contained items like 'bomb ballistics basic research £1 500 000' and even more vaguely, 'development contracts with industry £10 000 000'. It was a question of secrecy. In the House of Commons on 25 February 1952 Emrys Hughes MP asked the Minister of Supply how much the country had then spent on Woomera. The answer he received was dismissive. 'It would not be proper for me to say anything about [the government's] share in the expenditure nor in the public interest to disclose the amount and nature of the expenditure by Her Majesty's Government in the United Kingdom.' This was despite the fact that in Canberra only the week before the House of Representatives had been informed that Australia had pumped over £18 million into the project to date.[24] Britain persisted in being more secretive about financial matters than Australia. Even in 1954 Britain refused its partner's request to downgrade the Memorandum of Arrangements from Secret to Confidential. It refused on the grounds that the Memorandum contained information on the length of the Range and on how much money was being spent. In fact most of the first slice of British money—not joint project funds, strictly—was spent exactly as one might have expected: on extending the laboratory and office accommodation at RAE and adding supersonic wind tunnels, and on expanding the rocket propulsion test and research facilities at Westcott. To this day the details of the spending on the actual research effort have never been made public, except in the case of the civil projects and a few rare instances such as the cancellation of Blue Streak.

The Memorandum was an extremely simple document considering the very large expenditures made under it. Furthermore, it was a draft only and its first version was never formally ratified. Its most important clause read that 'the Commonwealth and UK governments will bear respectively that part of the expenditure in connection with this project which is incurred in Australia and the United Kingdom regardless of where the originating actions, e.g. orders, are taken'. It was retrospective to the beginning of the project and allowed for a review at the behest of either government. The only exception to the principle was that the cost of stores or equipment ordered from a third country by either party would be paid for by the orderer. Various arrangements were made about the cost of staff and travel, with a view to sharing them equally. This 'Dalton formula' (named for Hugh Dalton, the Chancellor of the Exchequer of the day, though it is unclear if he had any personal hand in it) was not received without criticism in Australia. Two of the forces representatives on the Australian Defence Research and Development Policy Committee thought it was unsatisfactory. The Army thought that Australia should bear only the costs of setting up and running the Range and none of the actual weapons development work. The Air Force representative thought that under the terms of the Memorandum both countries would theoretically have access to the results of all the work done at the Range, while in practice only the British would have access to the substantial research work carried out at home.[25] Presumably these objections were overridden.

When the Dalton formula was worked out—the formula that the costs should lie where they fell—the assumption was that most of the trials work at the Range would arise from the efforts of Britain's government research establishments. Such a simple arrangement worked well enough at first and with minor exceptions was honoured by both. But by 1953 some cracks were beginning to show. As Britain's Ministry of Supply put out contracts for military hardware to more and more electronics and aeronautical firms, these firms were encouraged, and also found it convenient, to establish Australian subsidiaries at Salisbury and elsewhere. In effect they were using joint project facilities: for instance, they were having their devices tested at the Range. It had never been spelt out with perfect clarity who should pay for the work done by these contractors on Australian soil, though for a few years Australia paid for it without demur, partly to avoid delays. But in the early years of the 1950s the size of the contractors' bills started to grow alarmingly. In the financial year 1952-53 it was a fairly modest £293 000, but by 1953 the prediction was that it would have more than tripled to £980 000 in the next financial year and after that would continue to expand indefinitely.

Naturally enough the Commonwealth—the departments of Supply and Defence, and most of all the Treasury—was becoming a little restive. The Treasury in particular thought the time had come to place a ceiling on Australia's possible indebtedness to the project in any one year. In a letter early in June 1953 to Menzies who was then in London, Minister for Supply Howard Beale cautiously expounded some of the economic realities of the project:

> In considering this matter of a ceiling I think it has to be borne in mind that Australia's participation in this guided missile programme is a unique contribution which only this country can make. Nowhere else in the world, I am assured, are facilities comparable with our guided missile range available. Without this range, the United Kingdom's programme of guided missile research and development would be hamstrung. For this reason, it might be felt that we should contribute the maximum support possible to ensure that from this valuable defence asset on which we have already spent about £29 million, the British Commonwealth should derive the maximum possible benefit.

Giving due regard to Menzies' anglophilia, and the fact that his personal relationship with Menzies was a prickly one, Beale had been careful to make his remarks as unexceptionable as he could. Woomera was indispensable to the British, and Beale well knew how Menzies was wedded to the notion that his country was providing an invaluable and appreciated service. Britain, Australia, the Commonwealth: to Menzies it was inconceivable that their defence interests should ever drift apart. Nevertheless . . . Britain could hardly expect to go on receiving a blank cheque. So grasping the nettle Beale went on:

> At the same time, of course, it would be unreal to ignore our other defence commitments or the total amount of money we can afford to allocate for our overall defence effort. This, I suggest, makes it desirable to determine what sum, within our total defence vote, it is reasonable to allocate for the guided missile programme and to advise the United Kingdom accordingly.[26]

Australian Minister for Supply Howard Beale (*right*) with Prime Minister Menzies during a visit to Woomera

Beale's rationale for putting these matters on a firm footing was that Britain would then be better able to plan its work within the ceiling and decide how much extra it wanted to pump into the joint project; but it is obvious that the real motive was to put some sort of a brake on the expense. No doubt Woomera was, just as Beale said, a 'valuable defence asset'; but it was not in the final analysis a priceless one: not to Australia at least.

The Treasury thought the ceiling should be fixed somewhere between £7 million and £9 million, and preferably at the lower end of that range. Defence and Supply both pressed for a £9 million ceiling, which Beale himself thought not unreasonable considering the scale of the trials program which the British wanted to undertake: in the course of a visit to Australia Minister of Supply Duncan Sandys unveiled details of nine new projects to be started up over the next few years. The final decision was of course for Menzies alone. Beale closed his letter by saying that 'you might discuss this matter with the United Kingdom Government while you are in England. Indeed, we suggest it [is] important that you should do so . . . It is certain that unless some steps are taken to solve the problem on the lines suggested, Australia will be faced with a continually increasing commitment for guided weapons work which will prove an embarrassment.' This last clause perhaps gets to the heart of the matter.

In a submission which reviewed the history of the project beforehand for the benefit of the Cabinet Committee, the Treasury took up the thorny problem of the contractors' costs. It pointed out that in the original estimates Australia had committed itself to spending £24 million on the Range over five years, and had detailed very exactly where the money was going. These estimates made no mention of the British firms' costs in Australia. The British, on the other hand, having received these estimates had taken another fourteen months to produce their own—and when they did come forth they occupied less than two foolscap pages. But sketchy though they were, these estimates did include the round sum of £10 million for development contracts with industry, so it was perfectly plain to the Treasury men that Britain had consciously allowed for the contractors' costs in Australia. It was true that Australia had supplied funds to keep the ball rolling, but this had been on the clear understanding that this must not prejudice subsequent negotiations. The question of these industrial costs should therefore not be allowed to become an issue in the negotiations at all. Of course Britain was honour bound to take them over; in agreeing to do so it was 'giving Australia nothing'. Such was the Treasury view. It grumbled a little too about Australia's paying for transport aircraft, but in the end the view prevailed that the sums were small and 'Australia should accept them as a fuller expression of the partnership principle'.[27]

Naturally the British had their own slightly divergent reading of the situation. To their mind it was important that the Dalton formula had not spelt out in so many words who should meet the industrial costs. Perhaps this was more than merely a matter of interpreting a fixed document. The agreement was unratified and it seems that more than one written version of it existed.[28] Britain also stressed that since 1950 Salisbury had ceased to be a place where only joint project work was done. With the return of the first batch of trainees Australia was able to embark on a modest guided weapons research effort of its own. In due course it would want to build the products of this research. Its willingness to give space to private enterprise at Salisbury was therefore by no means disinterested. The Contractors' Area would eventually become the core of Australia's weapons manufacturing capacity; indeed, the firms there were already doing work outside the joint project. There was nothing secret or underhand about this. It was a motive, probably the main motive, why Australia had entered into the 1946 discussions in the first place, and it had been recognised as a perfectly proper objective by both partners. But the British were reluctant to be saddled with the full cost of supporting firms that might have been bloated (so they suspected) by lavish Commonwealth financial assistance.

Whatever the force of these private hesitancies and varying viewpoints they did not prevent the two governments from quickly coming to terms: their mutual interests and goodwill far outweighed such minor embarrassments. Under the new Memorandum of Arrangements agreed upon and made public in September 1953, the distribution of costs was much more precisely spelt out. With the exception of the airframe of the Jindivik target aircraft and Projects E and J (two Australian anti-tank weapons under development) all missiles, bombs, launchers, guidance equipment, boosts and propellants, warheads, fuzes and motors would be paid for by Britain. So would all aircraft required for trials and all the fares and salaries of UK personnel in Australia. On the vexed question of industrial support—work done by firms and subcontractors in developing, assembling, workshop testing and modifying weaponry originating in the UK—it was agreed that practically every aspect of their requirements in Australia should be charged to Britain. This included their plant and machine tools, their salaries, stores, materials, overheads, power, water and so on.

Australia for its part agreed to provide all the civil engineering facilities, buildings and communications at Woomera and elsewhere; to install and maintain all apparatus; to transport all cargo and staff in Australia; to pay salaries for staff recruited in Australia, including those of staff sent temporarily to Britain; to house the contractors and provide them with 'landlord' services; and, finally, to pay for the cost of all trials and operating aircraft. Built into the agreement was the right of either party to request a review of it at any time in the future.

It is impossible to say whether one partner benefited under the new arrangements at the expense of the other. What can be said is that they shifted the burden slightly in both directions. Australia unloaded the considerable cost of the industrial work on to its partner; on the other hand, it agreed to take on half the costs of 'technical apparatus and equipment' built in Britain, and the heavy cost of extending the Range out to 640 kilometres. The partners issued a joint communique on 14 September 1953, each declaring itself satisfied with the new arrangement. From the British side the influential journal the E*conomist* told its readers that from now on the British taxpayer would be paying for most of the work at the Range. 'This seems to be a new definition of "sharing" of costs', it noted a trifle acidly, but it did not seriously question that Britain was getting value for money.[29] Certainly the Churchill government did not hesitate to sign the Memorandum when Menzies forwarded the document to Sandys with a covering letter asking 'whether you agree that the document expresses our common will in this joint enterprise, the success of which is so important to our two Governments and to the Commonwealth as a whole'.[30] As for the Australian Treasury's call for a financial ceiling, nothing more was heard of that for some time.

Notes and Sources

1. Evetts was instructed to work under an interim financial arrangement in which expenses would be incurred by each government in its own country on the understanding that the total costs would later be apportioned according to whatever terms were finally agreed upon. Instructions for Lt Gen Evetts dated 13 December 1946.
2. The Department of Supply, along with the project's British representation (the BDRSS organisation) moved to Canberra in 1968. The Swanston Street premises now (1987) house a branch of the Defence Department.
3. Reminiscence of Dr W. A. S. Butement at an interview of 23 September 1982.
4. In both the UK and Australia the names and responsibilities of the governmental departments and ministries responsible for joint project work went through some confusing evolutions over the years. In Britain the Ministry of Supply came into being on 1 April 1946 and lasted until 21 October 1959 when it became the Ministry of Aviation. MoA retained the powers of a supply department with regard to guided weapons research and production. The Ministry of Aviation ceased to exist in February 1967 when its functions were transferred to the Ministry of Technology. In Australia the Department of Supply and Development (formerly the Department of Supply and Shipping) absorbed on 6 April 1948 the Department of Munitions, which had been hived off from it at the beginning of the war. On 17 March 1950 a new department, called simply 'Supply' was created and lasted for many years, though eventually its functions were taken over by the Department of Defence or of Defence Support. In both countries the peacetime role of Supply and its cognomens was to stockpile and turn over strategic materials and to supply the armed forces with their equipment. It encouraged local manufacturers to produce what was needed and ran standards laboratories to check on quality.
5. W. A. S. Butement, 'Electronics applied to a number of problems: record of scientific work undertaken . . .' Unpublished DSc thesis, University of Adelaide, 1960, pp. 60-61.
6. Ivan Southall, Woomera, Angus & Robertson, Melbourne, 1962, p.43. Although all the main participants in the cancellation 'crisis'—Lockspeiser, Butement, Evetts and Williams—were still alive in 1985 and responded to inquiries, it has not been possible to untangle this episode completely. Lockspeiser himself cannot recall making such a decisive statement, and neither can Evetts: 'I cannot honestly say I remember him going so far as is implied in Southall's book.' The third member of the party, L. S. Williams, also finds it unlikely that Lockspeiser made such

an uncompromising announcement. 'He may well have proposed it or more likely suggested its deferment indefinitely. That could have been consistent with the Air side's view on priorities. However I do not recollect hearing of or seeing such a proposal.' Undoubtedly there were discussions between Lockspeiser and the visiting party, for the minutes of the Board meeting where Evetts reported on his UK trip mention them. The value of Butement's account, of course, is that it was written far closer to the events than any of the above reminiscences. The author wishes to thank W. T. S. Pearson for making inquiries on his behalf and for forwarding responses from Lockspeiser (10 May 1985), Evetts (14 November 1982) and Williams (14 August 1983).

7. Directorate of Guided Weapons Research and Development Newsletter No. 1 (September 1947). Red Hawk and Heathen were then regarded as a single weapon—the project was divided later.
8. Cablegram 102 dated 24 May 1947 from the Prime Minister to the Prime Minister. AA MP1748.
9. Minutes of Board of Administration meeting 10 of 22 July 1947.
10. Reminiscence of Sir John Evetts in a letter to W. T. S. Pearson dated 14 November 1982.
11. Minutes of CUKAC meeting 3 of 3 December 1947. AA MP1748 file GW/C/2.
12. 'The long range weapons project Australia. A note on the course of development and present and future UK interests—prepared by the Ministry of Supply. January 1950'. File 3/302/9. The bombardment drone continued to figure on successive CUKAC trials forecasts but always with the annotation 'for record' or 'no date can be forecast'. It solidified some years later as the Red Rapier expendable bomber, of which scale models were tested at Woomera. It should be borne in mind that these hesitancies and changes of plan reflect the tremendously rapid growth of knowledge, theoretical and practical, about guided missiles over these few years. The first supersonic wind tunnels allowed the problems of aircraft control in the transonic regions to be investigated. The hypersonic aerodynamics of rocket effluxes were being quantified. The atomic warheads were growing lighter all the time, reducing the demand on their carriers, and so on. It is not surprising that it was difficult to predict achievable weapon performance, let alone to forecast program dates.
13. At a high level meeting in London on 2 October 1950 between Sir Archibald Rowlands, Secretary of MoS, and his Australian counterpart H. P. Breen and others, the Australians expressed fears that the R&D facilities being built up in their country might not be exploited properly because of slow progress on long range weapons. Rowlands agreed to send a list of R&D projects which might be tackled jointly, and did so. It included items ranging from wireless sets to a short range version of the expendable bomber project. Most of the items were not guided weapons. Some afterwards prospered under separate UK-Australian agreements outside the scope of the joint project. PRO AVIA SG/1903.
14. Minutes of Long Range Weapons (LRW) Board of Administration meeting 33 of 3 February 1949.
15. Letter dated 9 December 1947 from J. B. Chifley as acting Minister for Defence to Minister for Munitions J. I. Armstrong.
16. Minute dated 19 March 1948 from CEO Evetts to Board Secretary E. L. Cook. AA MP1217 box 1910 file GW/P/3.
17. Letter dated 30 March 1951 from Secretary of Department of Supply H.P. Breen to Controller of Munitions Supply.
18. Letter undated [but about 15 August 1951] from the Secretary, Department of the Prime Minister to the Office of the British High Commissioner.
19. Quoted in Rohan Rivett, David Rivett: fighter for Australian science, Rivett, Melbourne, 1972, p.2.
20. Minutes of LRW Board of Administration meeting 1 of 7 August 1947.
21. Report dated 7 October 1947. AA AP589/2 box 6.
22. 'Professor on research on "guided missiles" ', Advertiser, 15 July 1946.
23. Reminiscence of Bob Edgar of Radio Group, at an interview of 17 November 1983.
24. Referred to in a letter dated 26 February 1952 from the UK High Commissioner's Office to Secretary Prime Minister's Department A. S. Brown. DOD file 3/302/9 on loan to DRCS. File A5720/10/17 refers.
25. Extract from the minutes of a meeting of the Defence Research and Development Policy Committee held on 5 October 1949. Copy on DOD file 3/302/9.
26. Letter dated 8 June 1953 from Minister for Supply to Prime Minister Menzies. Shedden Papers box 1388.
27. Minutes of the Cabinet Committee meeting held at Parliament House on 10 September 1953. Shedden Papers Box 1388. At this meeting Menzies was in the chair, and other important

members were the Treasurer Sir Arthur Fadden, Sir Philip McBride (Defence), E. J. Harrison (Defence Production) and the Hon. Howard Beale (Supply).

28. Detailed in a 'Note on the UK approach to the Sandys Agreement' prepared for this History by W. T. S. Pearson.
29. 'Footing the bill at Woomera', Economist, 26, September 1953.
30. Letter [undated, but September 1953] from Australian Prime Minister to UK Minister of Supply Duncan Sandys. Most press commentators took it for granted that the new agreement determined Australia's payments towards the forthcoming atomic tests at Emu, but this was incorrect. The expenses of the tests were (in theory) distinct from the joint project and were the subject of separate financial negotiations. Australia had in fact paid £201 662 towards the Monte Bello tests of the year before and eventually paid £134 000 towards the Emu tests. By comparison with the huge joint project expenditures these amounts are trivial. Information from the Shedden Papers box 1388.

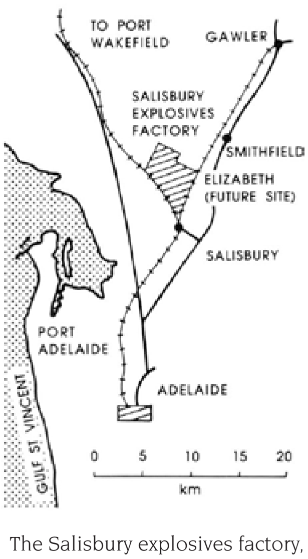
3 Living and working at Salisbury in the early years

TRANSFORMATION OF A MUNITIONS FACTORY

The facility which was to become the base technical establishment of the joint project began as a sprawling complex of buildings north of Adelaide known as the Explosives Factory Salisbury.

In the middle of 1940, in the wake of Dunkirk when the Allies had suffered devastating losses of war materiel, the Australian War Cabinet directed Essington Lewis, the Director General of Munitions, to find a site for a new explosives factory. The only existing one, at Maribyrnong in Victoria, had no room to expand further. Two possible candidates were Albury and Adelaide. In eager pursuit of the policy of industrialising his State, South Australia's Premier Tom Playford pressed the advantages of Adelaide, and as an inducement his government agreed to pick up the bill for supplying land, water, roads, power, transport and sewerage. Playford, a shrewd and far-sighted man, had in mind the long-term advantages of such a deal: when peace returned South Australia would gain a ready made industrial park. From the other side Playford's offer was apparently one Canberra could not refuse, for the decision in favour of Adelaide was made in a mere fifteen days.

Acting under the Supply and Development Act of the previous June, the Commonwealth compulsorily acquired from some twenty pastoralist families 2200 hectares of wheat land between Salisbury and Smithfield. Apart from its lack of water, a handicap overcome by bores and a pipeline from the Barossa reservoir, the site was an excellent choice. It was distant enough from Adelaide for its activities not to be hazardous, yet close enough to draw on a workforce of thousands and, occupying as it did the land between the Gawler and Port Pirie railway lines, it had no problems of access.



The Salisbury explosives factory, built during World War II, was placed far enough from Adelaide for safety yet close to rail and road links.

The construction of the factory began in November 1940 and demanded a prodigious effort. It was the Commonwealth's biggest single construction work of the war, and by far the biggest in the history of South Australia. At this time the State's economy was for the most part rural and Adelaide was not much more than a large country town: neither was really up to handling a project of this magnitude. So heroic measures were called for; so heroic indeed that there were some initial complaints that the work was being planned on too lavish a scale. Every private architectural and structural engineering firm was put to work draughting the plans, and the expertise of many state government departments was fully tapped. The general design of the factory was based on Maribyrnong. The main difference was that Maribyrnong had been built mostly of timber and asbestos. These materials, as well as carpenters, were in short supply in South Australia, which however had spare brickmaking capacity and bricklayers. After some argument about the expense, brick construction was decided on to the benefit of the future, for the resulting buildings had a solidity and permanence which belied the haste with which they were erected. To save time the Department of Works dispensed with tenders. It set up a team of about 110 people in Adelaide, including a panel of builders who costed the various jobs, allocated the work and made payment accordingly.[1]

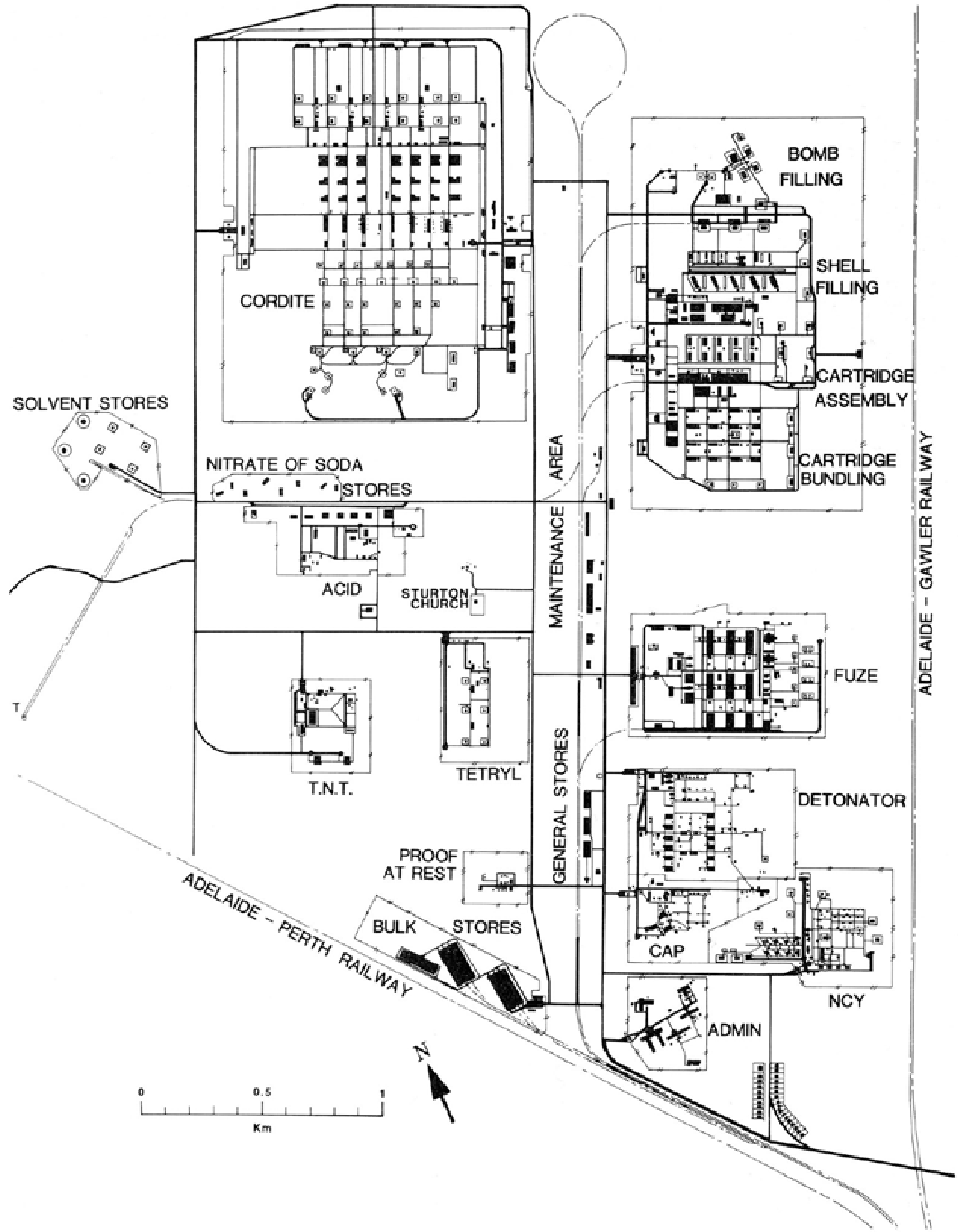
The State's entire production of bricks was appropriated at a fixed price—fifty million were eventually laid—and this automatically froze all other construction work and freed other materials and labourers. Only the SA Railways' Islington works could handle the heavy mechanical engineering, especially the high pressure steam plant; and R. H. Chapman, Chief Engineer there, became assistant to the Superintending Architect, W. T. Haslam. The chemical plant was the work of Shell Australia and ICIANZ, who designed and installed the TNT and Tetryl plants respectively, although neither had much munitions experience. At the peak of construction 3000 labourers and tradesmen were working seven days a week on the site, and throughout 1941-42 the access roads were carrying an unending stream of materials. Some workers commuted by train from country towns like Kapunda and Eudunda; others who lived in even remoter towns found lodgings or else lived as best they could in caravans, overcrowded sheds, or even in rough humpies on open allotments. In their short hours of leisure they amused themselves riotously. The bucolic calm of Salisbury, a community previously known only for the high quality of its hay, was entirely disrupted, and the number of arrests, especially for drunkenness, more than quadrupled in the single year 1940.[2]

Despite contretemps like vital materials which had been addressed to 'Salisbury SA' being shipped to South Africa by mistake[3], the building went forward with incredible rapidity. Harold Argent, a worker on the farm of one O'Leary which had been purchased, recalls that the surveyors who marked out the sites for buildings in the paddocks had to be called back to drive their pegs in further so the last crop of hay could be cut.[4] The little community of Penfield was engulfed, including a number of old farmhouses, some of which still stand. One of the most attractive and noteworthy of the historic buildings remaining on the site is the Sturton Methodist Church. (Sturton was the original name of part of the Salisbury area.) This church was built on land given for that purpose in 1856 by the Jeffries family, descendants of the infamous Judge Jeffries of the Bloody Assizes. By the time the Commonwealth acquired the land the church had fallen on hard times and was being used as a barn. After representations by a member of the family, the government restored it and it is used for services to this day by the Christian Fellowship of the Defence Research Centre Salisbury staff.[5]

In the place of Penfield arose 1595 buildings offering more than eleven thousand square metres of workspace, many widely dispersed across the open paddocks because the British Home Office specifications of the time required that buildings containing explosives should be at least 46 metres apart. Many kilometres of power lines, roads, sewers and railway were also built, and the whole site circumscribed by manproof fencing with more around the sections. Looking after the sweeping open spaces around and between the buildings was a taxing responsibility. Heavy plantings were needed as windbreaks as well as for aesthetic reasons. From 1943 the grounds were maintained by three men, including Josh Willing, the head gardener, who really did wear a wide-brimmed hat with dangling corks to keep the flies off. Their first task was to plant windbreaks around the edge of the site and to establish lawns, ornamental trees and avenues. Nearly all of the trees on what is now a heavily wooded site have been planted since then, including no fewer than 35 000 by the time the project took over at the end of World War II. The slopes on the protective mounds round some buildings were so steep and the earthen drains so deep that mowing was impossible with any kind of machinery available at the time; running sheep was the only practicable solution to ground maintenance. At first sheep were set grazing all around the buildings, so closely that their droppings were tramped inside. Later they were fenced off in paddocks, but from the start they flourished on the rich pastures around the factory and became a profitable enterprise. In 1948 when the flock numbered 2000, merino wethers were fetching £3 14s a head, and were therefore a good asset when transferred on to the project's books.

The result of these varied labours was that the Percussion Cap section was able to start production within a year of construction beginning, and the others by the end of 1942. The manufacture of munitions at Salisbury, which continued until August 1945, was on a broader scale than anywhere else in the country. It included nearly all the agents of mass and individual destruction: the manufacture of explosives and propellants such as nitroglycerine, cordite, TNT and tetryl, and the filling of shells, cartridges, mortar bombs, percussion caps and depth charges. So great was the demand for these melancholy but necessary products in the latter stages of the war that by early 1944 the acid, cordite and maintenance plants were working three shifts around the clock turning out nearly 100 tonnes of TNT every week. All in all, the factory with its capital value of more than £7 million was South Australia's prime contribution to the call for 'total war on the industrial front'.[6]

The workforce reached its maximum strength in February 1943 with 6400 employees, but rapidly declined thereafter to about 1850 by the end of the war. The transport of such an army caused Salisbury station to buzz with activity as workers from Adelaide and the country towns changed trains, and there were arrivals at and departures from the three Penfield sidings night and day. The fastest train from Adelaide took eighteen minutes, and the fare right through the war was 4 shillings a week return. Including travelling time, a



The 1595 buildings of the explosives factory were in several dispersed areas in the generous 2200 hectare grounds.

working day of twelve hours was commonplace. Yet even so, some ex-munitions workers vividly remember the high morale at the factory, the general cheerfulness, the sense of doing a vital job. Ron Smoker, an electrician, recalls that while brawling and drinking on duty were far from uncommon, 'there were very few strikes, maybe because the hours were so long you just did your job; you were too tired to argue'.[7] But enough of them had some energy left over to make the Munitions Club in Peel Street in the city a popular haunt.

The factory's workforce was made up of about equal numbers of men and women. Most of the men were in reserved occupations and not allowed to enlist, but some had seen active service and had returned wounded in body or mind:

> We had quite a few men who returned from the War with shell shock and that. We had a few of those working out here after they came back, especially in the area where the empty shells were cleaned from rust and so forth. It was nothing to be going along inspecting an empty shell and somebody would grab you and throw you under a bench crying, 'they're coming, they're coming!' If you knew they were going to have one of these turns and if you could stare into their eyes, you could prevent them lots of times from doing anything further. Afterwards they knew they had done something but they didn't know what. They used to feel terrible about it; really embarrassed.[8]

Some of the many women on the production lines.

Some jobs such as making and filling detonators were entirely the province of women. Though some women had always been employed in munitions factories elsewhere in Australia, they had never previously been used in detonator and fuze manufacture on such a scale. So many women were employed, of course, because far fewer men were available. Also the fuze section consisted of some hundred metres of production line, and women were considered to be more reliable at this repetitious work. At first the line was called 'Willow Run' after Henry Ford's famous pioneering venture into mass production, but the hard-pressed women soon renamed it 'Burma Road'. The third reason for using women was economic: women were cheaper. At the outset they were being paid less than 70 per cent of the men's wage, and even at the end of the war it was still only 80 per cent. But even so wages were excellent; they ranged from .£5 to £8 a week, double a shopgirl's pay. The first group of women were recruited in July 1941 by the simple expedient of having a member of the Manpower Commission and a female welfare officer travel around the department stores and hotels selecting likely assistants and waitresses. Strictly speaking civilians could not be conscripted, but they were told that they were now 'disemployed': their old jobs had simply ceased to exist. Work was still to be had, but it was to be had only at Salisbury. Few women, used to the more genteel atmosphere of Myer and the other stores, took kindly to the idea of factory work dressed in blue serge 'giggle suits'. To deal with this, the recruiters' strategy was to divide them into groups, listen to their noisy protests ('We're not staying here and getting nasty yellow skin!'), and then engineer an exchange with one of the married women along the following lines:

> 'Where's your husband stationed, dear?' 'Up at Darwin.'
>
> 'Oh, is he now? Well, I'm sorry to hear that, because he's going to be in strife pretty soon. You see, they need ammunition desperately up there . . . No use him coming to us, because we're not making bullets this year: we can't get the workers.'

This ploy was usually sufficient to revive the flagging patriotism of the 'volunteers'.[9]

If work at the factory was hard for everyone, for some it was unhealthy and for a few positively dangerous. The high explosives were toxic, for nitroglycerine depresses the blood pressure and TNT can cause liver damage and dermatitis in susceptible people. John Lewis, author of a local history of Salisbury, recalls working for five weeks alongside thousands of others in the TNT section on the 12 p.m. to 8 a.m. shift. He describes the horrible smell of the hot yellow trinitrotoluene and how, despite rigorous precautions—compulsory showers, special soaps and constantly renewed work clothes—the smell so permeated the skin as to be almost ineradicable.[10] Regular medical checks and better precautions eventually solved the dermatitis problem, but the reddish orange fumes from the molten TNT as it was poured into shells even contaminated the paint on the walls, and despite the monthly blood tests TNT toxaemia was the official cause of at least one death. Life in the acid plant had its risks too. Old fashioned tin baths were scattered about filled with an alkaline solution. When a man was splashed with acid he was not disposed to dawdle:

> If the acid hit you on the hands you dunked your hands in, but if it hit you on the body or the face or anything, you made a beeline for the bath and dived straight in. You had to hold your breath long enough to neutralise the acid.[11]

These workers were also encouraged to drink a pint of milk every day. Those who suffered the greatest risks of all, though, were the women who had to tackle what has been called 'the most dangerous operations carried out in *any* industry'[12]: the manufacture and handling of the extremely sensitive lead azide and styphnate used in detonators. A

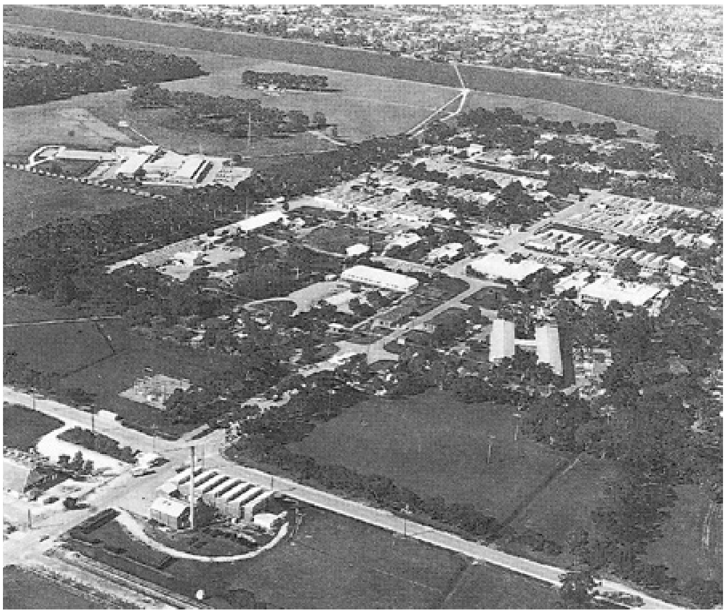
Miss Edna May Purling met her death early one Monday morning in October 1942 when some styphnate she was weighing got knocked over. The fact that this accident was the sole fatality during the whole life of the factory is testimony to its safety precautions and strict controls, still more remarkable when one appreciates that only six of the more than a hundred production staff of chemists and engineers originally knew very much about explosives manufacture. Great stress was placed on holding the clean areas free of all contamination from the outside. When workers came on duty they removed all their day clothes, put them on hooks and after drawing them into the air with a pulley device for safe-keeping donned loose suits with wooden toggle fasteners. Cleanways between sections and gritless floors of asphalt mixed with limestone reduced possible friction sparking. Shoes had no metal components; the soles were sewed on and the heels fastened with wooden sprigs. Watches were forbidden and those who would not remove their wedding rings had to have them taped over. These regulations were enforced in the sections. Discipline was strict everywhere; in 1943 alone, 160 people were sacked for misconduct including breaching the safety regulations. But even these measures did not prevent severe if non-fatal accidents, such as blowing off the tops of fingers, which occurred periodically. In those exigent days they had to be treated more or less as occupational hazards. The on-site hospital wards and operating theatre saw plenty of patients, and those inclined to be insouciant about the work hazards perhaps had their attention jogged by catching sight, at a discreet distance from the main buildings, of a blocky structure which was the morgue.

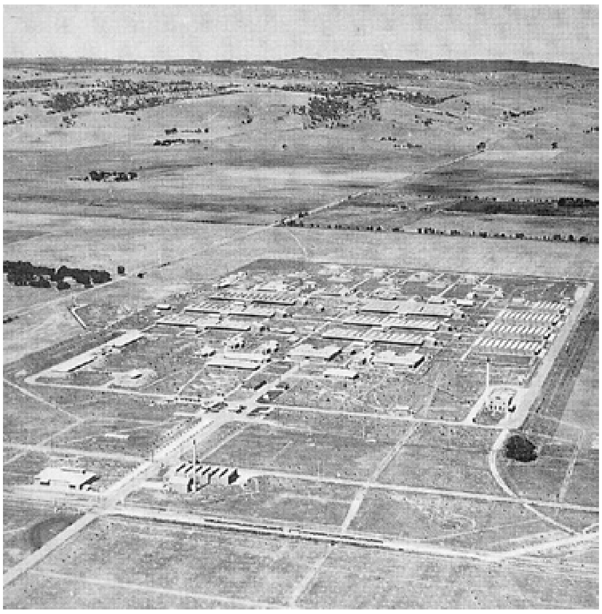
Another kind of risk was taken just as seriously and precautions were taken just as thoroughly. The bombing of Darwin showed that the threat of Japanese air raids over southern Australia could not be discounted entirely. If they ever did take place, Salisbury would assuredly be a prime target, and in recognition of this some key buildings were camouflaged and blackouts practised. Weekend volunteers dug concrete shelters, the telephone exchange was 'hardened' with blast walls and a siren system installed. An air raid precautions officer was for a time rostered right round the clock and regular drills took place; a laborious exercise because the shelters were outside the clean area, and everyone had to go through the showering and changing ritual afterwards. Fortunately these provisions never had to measure up to an emergency.

A long-abandoned building in the old TNT area, 1987

After the war ended with Japan's capitulation in September 1945 the factory's workforce quickly shrank away. The peacetime demand for labour far exceeded the supply, and the new industries then starting to establish themselves in Salisbury had jobs for the asking. Many women simply went back to the pre-war jobs from which effectively they had been drafted. A few maintenance foremen and tradesmen were in due course invited to transfer to the new Long Range Weapons Organisation. By November only 300 people remained on the payroll, mostly engaged in decontaminating the plant of toxic and explosive residues. The last traces were not easily expunged. Despite the best efforts pockets of explosive powder lingered on in gaps in cornices and architraves for months or years, ready to detonate with a fearsome crack on contact with a cleaner's brush. Outside, the great wooden trestles of the elevated walkways were pulled down and their timbers later recycled at Woomera, and three large boilerhouses were also demolished and the plant used in the Woomera powerhouse. Other plant was cleaned and stored away, or else liquidated. Some huge and valuable mixers used for preparing mineral jelly went to a biscuit manufacturer, and scrap metal merchants had a boom in business. Other useless plant was 'consolidated and left', and some abandoned hulks of buildings, collapsed chimneys and rusting vats can still be seen forty years later. Finally, with a touch nicely symbolic of the new era of peace, a large quantity of junk was put into a condemned barge which was scuttled in 100 fathoms off Kangaroo Island.

Soon after the war munitions factories everywhere in Australia started to fill up with commercial tenants. In NSW, St Mary's Filling Factory became home to eighty-nine firms between 1946 and 1948. Fortunately, only three firms[13] were leasing some small parts of Salisbury when the project first recognised its possibilities. It was swiftly withdrawn from the list of munitions establishments to be disposed of, and the firms—Allison Textiles Ltd, the Ex-servicemen's Co-operative Joinery, and L. Chalmer (SA) Pty Ltd—were given notice to vacate. Formal approval of the project's occupancy came in September 1947, but then six of the Evetts eleven, Rowe, Butement, Bayly, Hunwicks, Pye and Caddy, had already been installed there for seven months. It took time to work out how much space would be needed altogether, but for a start the project was temporarily housed in the south-east section of the factory where were situated the Administration block, the Detonator, Fuze





The Laboratories Area in 1983 (*left*) looking towards Elizabeth. The two differently oriented buildings are the only large ones built since the war. At the right is a 1946 view of the same area.

and Engineering Workshops, the Carpenters' Workshop and the bulk stores. (The initial plan was that the Department of Munitions should keep the TNT and tetryl shops intact, in case they needed to be put back into production, and this move was briefly considered at the time of the Korean war.) The Britons, used to austere accommodation, at first feared that Salisbury would turn out to be just a bleak set of ordnance factory buildings, and were rather dazzled when they discovered how lavish the facilities actually were. R. W. Pye noted that in the initially allocated area alone 'there is no difficulty in finding other buildings; there are literally dozens—air- conditioned and all services laid on—any of which will do'. A. P. Rowe was even more enthusiastic, 'the facilities here would make any boffin's mouth water'[14] and they reinforced their message by sending photographs to Tizard and to RAE Farnborough showing the excellent fittings and the lovingly maintained lawns. Early in 1948 the project took over the accountant of the factory and his staff, and was thereafter responsible for the whole Salisbury complex, recovering costs from those sections still outside LRWO. After Salisbury passed formally into the hands of the project on 29 March 1948 great quantities of plant—canteen and workshop equipment, boilers, air-conditioning, and general stores—were transferred to its books.

One description of the appearance of Salisbury during those first chaotic months comes from the pen of a *Sydney Morning Herald* reporter who toured the Salisbury plant for five hours in June 1948 at the time of the most intense activity. He was most struck by the 'vast emptiness' of the hundreds of deserted buildings, and he thought that bearing in mind how quickly these had been erected in the first place it had to be said that 'the physical progress made in the last twelve months seemed pitifully small'.[15] Nevertheless, as he toured through a series of new labs, workshops and weapons assembly bays he saw, besides a 'museum piece' V2, some impressive electronic and photographic gear and a vast assembly of miscellaneous stores. Much of this stock had come from Royal Navy depots at Bunnerong, NSW where Caddy and Bayly had examined them the previous year, unfortunately arriving to discover that practically the whole lot had already been auctioned. What was left became one of the first material contributions of the British to the project, soon to be supplemented by other consignments on board the liners *Corinthic* and *Papanui*.

All things considered, adapting the Explosives Factory to its new role in a more complex era of military science was accomplished with surprisingly little fuss, and with the benefit of hindsight we can see what a good choice had been made. Over the intervening years the grounds have seen more changes than the buildings, which adapted well to nearly all the later requirements. Under the management of its curators, the Establishment continued to run sheep over its own hectares and those where Edinburgh airfield was eventually built, and for a long period they produced an income equivalent to many tens of thousands of dollars a year. A flock of 5500 was finally sold late in 1982 for the excellent price of $33 a head, though sheep are still run under contract. Planting of the grounds continued, and over a quarter of a century (1959-1982) curator Matt Fitzgerald and his men—he had charge of a force of fifty-five at the peak—planted another 25 000 trees including more than fifty varieties of eucalypt all of which were raised from seed. Many remnants of war were obliterated by their industry: the static pools were turned into fishponds with many species of fish and waterlilies, and the air raid shelters, serious eyesores, were cunningly landscaped and their entrances disguised by large shrubs and cacti. Apart from the wind tunnel, for which a contract was signed with a Port Adelaide firm of metal fabricators in April 1952, and some static test stands, the only new structures on the site are the two laboratories 171 and 180, though it is true of course that many buildings have been gutted and rebuilt for purposes very different from those intended by their architects.

'PASSES PLEASE!'

LRWE—sometimes translated as 'Lambs, Rams, Wethers and Ewes'—continued to run a large flock of sheep to control the grass.

HOMES FOR THE WORKERS

Though the business of the project was housed efficiently and easily, housing its rapidly expanding army of employees was an intractable problem for some years. Even the six members of the Evetts eleven who took up residence in Adelaide were not immune. Back in England they had been told that they would have to find their own housing without help from the Organisation, though somehow the impression was conveyed that this would not be too difficult: Australia, after all, had its housing stock intact. A rude shock awaited them on arrival. Caddy, who had private means, found himself a pleasant house in North Adelaide. The rest had to put up with long stays in hotels, small expensive flats, or holiday shacks in the beach suburbs.

The real situation was that in Adelaide just after the war the labour market was buoyant and the price of housing high. Every kind of worker was in short supply, and the project had to compete with electronics and engineering firms that were tooling up and taking on staff to meet the heavy demand for consumer goods. Working for the Commonwealth had its advantages—the pay was very much better than private employers were offering—but unless one could find somewhere to live locally, working at Salisbury meant resigning oneself to that tiresome commuting trip from the city which added more than an hour to the working day. From the beginning the authorities recognised that the recruitment of staff for the project demanded inducements, and the most potent inducement at the time was the guarantee of a house. Housing was in critically short supply in every capital city of Australia, and Adelaide was no exception. The offer of a job plus a house in either the northern suburbs or Salisbury itself was a great magnet even to the upper echelons. It was powerful enough to help lure over from Melbourne Bill Boswell, who eventually became the much loved Director of the Weapons Research Establishment and piloted it through its most exhilarating years.

Eventually the presence of the Salisbury base with its several thousand employees transformed the human landscape of the area. It generated much of the growth in Salisbury township itself and was instrumental in the selection of the site of the new town of Elizabeth in the mid-1950s. But for the first few years houses were in desperately short supply. All the Establishment itself could offer was a hostel, converted from the munitions factory hospital, that could accommodate just forty- two single men. Near the perimeter of the compound were a few old houses along Penfield Avenue, and these were supplemented by ten new houses for the very senior staff. Whether one was housed on the 'right' or the 'wrong' side of this avenue was a question of agonising import to some of those fortunate enough to be living there at all. Later on a few munitions factory buildings were converted into blocks of flats, but that was all: there was nothing else. As more and more staff began to arrive from interstate and Britain, more drastic measures were resorted to. The Minister for Munitions himself talked to the Licensed Victuallers' Association to persuade hotels in Adelaide to put up staff and their families as permanent lodgers. The more important people did have the definite promise of getting a house eventually. In June 1947 the government had reached an agreement with Premier Playford that a state instrumentality, the SA Housing Trust (founded just before the war to house low-paid workers near their jobs), would build a hundred or so houses in Adelaide and sell them to the Commonwealth, which in turn would rent them to LRWO tenants. The houses were good detached brick homes of mixed designs, costing the respectable sum of £1700 or £1800 each. The annual rent of each house was set at a very modest 7 per cent of its capital value, though at the time some thought even this was an excessive amount.[16] The houses were in the nondescript suburbs of Enfield North and Blair Athol which were then on the extreme northerly fringes of Adelaide, and from there one took a leisurely drive along a narrow country road past the tiny township of Salisbury to the Establishment. The setting was nothing grand—for years the footpaths were unpaved and the streets unsealed and treeless—but the engineers, administrators and technical officers who lived there were doing well enough by comparison with others. They tended to stay for ten years or so, by which time they had accumulated enough savings to move to a better suburb.

'Moculta', the only pre-war house in Penfield Avenue and the most spacious. It was occupied for a time by Bill Boswell when he was Director of WRE.

Such houses were of course only for the elite. They were a drop in the bucket considering the total needs of the professional and industrial staff at Salisbury. As the shortage grew ever more acute, speculative eyes turned towards a group of battered prefabricated houses that had been standing in untidy rows on the outskirts of Salisbury ever since the munitions factory had been in production.

The decision to build these 'temporary' houses for the munitions factory workers had been made late in May 1942 after much discussion between Commonwealth agencies, the state government and the SA Housing Trust. The Trust did not share Playford's faith that the factory site had any future after the war, and it was only prepared to build houses for munitions workers in the already established industrial suburbs of Adelaide. The task of accommodating some of the workforce was therefore handed over to the Commonwealth War Workers Housing Trust (CWWHT), which eventually put up 284 'War Workers' Cottages' (known to everyone as Cabin Homes) on twenty-two hectares near the factory. More than a thousand people came to live in the cabin homes, unattractive though they were. Their scruffy appearance and shoddy quality was the result of two factors: Canberra's not unreasonable determination to spend as little as possible on them in the middle of the war when they would presumably be pulled down after it ended; and the fact that they were administered by a remote authority knowing little and caring less about local conditions. According to the CWWHT the cabins supplied, 'the Minimum and Maximum standard of housing which could be provided with the needs of the worker and of economy, time, materials, manpower both taken into consideration'.[17] The cabins did indeed offer minimal benefit of shelter close to the munitions factory. They offered little more, however. The overriding concern for economy was painfully evident. Both the cabins and the estate itself were lacking in a number of services necessary for comfort or even for health. The living area of each cabin was tiny and storage space was quite inadequate. The bathrooms lacked showers. In the taxing climate of the northern Adelaide plains the cabins were built on an almost treeless site, with no shade for the windows facing north and west. Flyscreens were deemed to be unnecessary, and it was impossible to ventilate them properly without letting in flies. The most serious problem was that, because the houses were on Commonwealth land, the munitions workers paid no rates to the District Council and so did not enjoy its amenities. The lanes were unsealed and homes unsewered. Not surprisingly, this unsavoury estate was the scandal of the old residents of Salisbury, and it did have more than its share of social problems.

B. S. McCarthy, Principal Administrative Officer of LRWE.

After the war the cabin homes were not pulled down, of course; and indeed they were still fully occupied when R. W. Pye suggested diffidently to Evetts that as they became vacant these poor dwellings might be used to relieve LRWO's housing strain. Evetts, over in Melbourne, did not think much of this; 'cabin homes are regarded purely as a temporary solution of the past housing problem which, although admittedly becoming of a somewhat semi-permanent nature, are not regarded very attractively. It is not quite clear whether the type of home offered would attract personnel.'[18] But in reply Pye said that recruitment was going badly and they needed something as a drawcard. He emphasised that the cabin homes would be used only as long as a dire need existed, and the idea was eventually approved on that understanding. Both these officers vastly underestimated the demand. A huge waiting list immediately sprang up. The LRWE administration began to receive pathetic letters from people for whom obtaining a cabin home tenancy was a wistful dream—a distant dream, indeed, for in the full year 1948 only nine cabins were vacated. 'Dear Mr McCarthy', wrote a maintenance store worker to the Principal Administrative Officer:

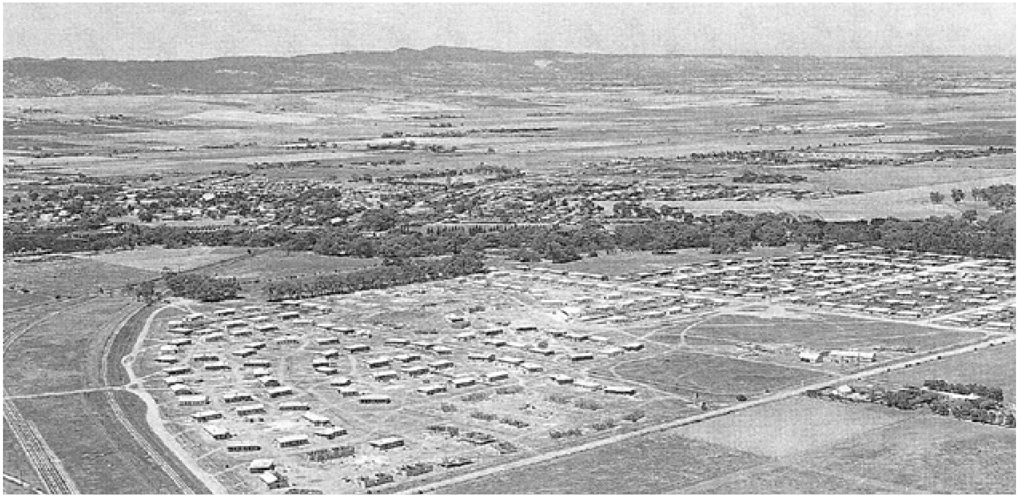
> I realise it may be somewhat irregular for me to contact you in this manner, but to me this is a matter of the utmost importance . . . I am a returned serviceman, and while I realise a Cabin Home is difficult to obtain, especially with more important men than me probably waiting for somewhere to live, such a home would be Heaven to me. If I should, at a future date, be fortunate enough to be allotted a Cabin Home, I am prepared to be married at One Weeks notice. Well, Mr McCarthy, if this letter should be irregular you may reprimand me but I guess I cannot be blamed for trying.

McCarthy replied personally, gently pointing out that many of those waiting were in desperate need, with large families. This information was enough to precipitate the inquirer into matrimony:

> Since last writing you, I have been married. I understand that not having children may be a drawback, but what on earth can I do. At present we are living with my brother, also in a Cabin Home, that being the only accommodation available to us. He has three children, so we occupy the back verandah. How can we have children under these circumstances? However I am afraid we may have to.

In an attempt to allocate the cabins fairly, the administration drew up a list of priorities and it is a measure of the problem that a man and his wife with three children who were living 'in a beach shack lined with bags' rated only Priority 'C'.[19] A few years later, in 1953, the Commonwealth Department of the Interior tried tentatively to start disposing of the cabins by suggesting that those who were still waiting for housing might be accommodated in a Trust home. LRWE quickly responded with the information that families were moving into the new Trust houses only at the rate of nine a month. By this time 130 of their employees were in cabins and a further 106 families were still eager to obtain one; nor was the situation likely to ease when the RAAF were on the point of moving down from Mallala to Edinburgh. After this the cabins were left alone. The men who erected them in 1942 as a wartime emergency measure doubtless would have been surprised to find them decrepit but still standing for their twentieth birthday. They were finally demolished in 1964.

The Housing Trust estate at Salisbury North, which started to take shape in 1949, was built explicitly to house the 'industrials' of LRWE, on the argument that these grades would be most attracted by the idea of housing close at hand. It was the largest residential development in the region until the new town of Elizabeth began to rise along the eastern boundary of the Establishment a few years later. The original conception had been that apart from a small 'model village' of forty or fifty houses close by, the LRWE housing should be scattered through the community to avoid the effect of a ghetto. But when it came to building Salisbury North these advanced notions were forgotten, for the economies inherent in making it an estate development were too great to ignore. It is unfortunate that the estate was born at a time when both money and materials for housing were in short supply. The houses of Salisbury North were intended to be permanent, unlike the cabin homes, and



Salisbury North in 1953 when construction was still in progress. It was intended as a nearby dormitory suburb for LRWE. Beyond it is Salisbury, then a small town.

Bagsters Road, Salisbury North, in 1956. By then the road was sealed but footpaths and kerbs unmade. At the left is a row of maisonettes with mesh fences.

their deficiencies have become a permanent part of the Salisbury urban landscape. Most of the houses were maisonettes of Mount Gambier limestone. A local historian has described them thus:

> low cost structures . . . of monotonous form, being identical to each other, endless in their rows, all with a rusting chainwire mesh fence and weathering to that insipid yellow/brown of weathered limestone. Their appearance could be said to be the trademark of any Public Housing Authority in Australia of the immediate post-war era. In their architecture a mark of contempt seems to be expressed for the people in residence.[20]

The slovenliness of the domestic architecture was matched by the absence of even a rudimentary attempt at town planning. The powers of the Housing Trust were limited at the time merely to putting up houses. It could not build shops or roads or footpaths, let alone community amenities like halls, playgrounds or parks. Not a single public telephone graced a street corner until the end of 1952. The estate was not even sewered until the beginning of 1955, and until April 1953 the tenants were officially instructed to bury their sewage themselves in their backyards, and this at a time when nearly 300 families were living there.[21] The natural setting reinforced the problems of the inhabitants. Much of Salisbury is low lying and prone to flooding, and in the winter the unmade roads could be quagmires. Bagster's Road, leading to the Establishment, was a mere mud track. Employees used to come to work in heavy gum boots, walking because the road was impassable to vehicles.[22]

The Establishment's representation in Salisbury North was very high for years. In 1951 three-quarters of the houses were going as soon as they were finished to families nominated by LRWE and the contractors. The other quarter went to Education and Police Department people and to other needy families in the area.[23] In September 1955 a report to the General Manager of the Housing Trust calculated that, out of the initial allocation of 1000 houses, 850 were now home to employees of WRE and its associated industries.[24] At first the estate's social mix was wider than had been envisaged. With the absence of anything better to go to, every class rubbed shoulders there, from the men of the Commonwealth Investigation Service to Experimental Officers to toolmakers. The social life was active, if narrow in range. Gradually, however, a combination of the dreary surroundings and better mobility drove away most of those who could afford to move. Some went to Elizabeth and some to the spanking new suburbs that in the early 1960s began to creep over the northern Adelaide Hills. Salisbury North ceased to be a WRE stronghold and became instead the monolithically working class suburb it is today.

Notes and Sources

AA holds a Department of Supply and Development file (S/51) of materials for a draft history of the Explosives Factory, consisting of contributions obtained soon after the end of the war from officers in charge of the various sections (MP438/3). The Managers' Reports are a further source of information: MP959/37 file 245/542/21.

1. Information from Jack Cheesman, then of the Department of Works, dated 28 October 1983. As far as the author has been able to ascertain, the persistent story that the design of the factory buildings was copied slavishly from the plans of a Scottish facility, right down to the 'snow traps' at the doorways, is totally fictitious.
2. Margaret Allen, 'Salisbury (SA) in transition.' Unpublished MA thesis, University of Adelaide, 1975, p. 15.
3. Reminiscence of Reg Moroney, a chemist at the factory, in an interview of 17 May 1983.
4. Reminiscence of Harold Argent, a carrier during the construction of the factory, in an interview of 29 June 1983.
5. May Broughton, 'Early history in church and orchard', Chronicle (Adelaide), 9 November 1973, p. 30.
6. David Paver Mellor, The Role of Science and Industry. Australia in the War of 1939-1945, Series 4: Civil vol.5. Australian War Memorial, Canberra, 1958.
7. Reminiscence of Ron Smoker, who worked at the factory from 1942, in an interview of 27 May 1983. A manager's report confirms that, 'it was only with the greatest difficulty that it was possible to stamp out the practice of bringing liquor into the Factory Reserve, or arriving at work under the influence'.
8. Reminiscence of Mrs Ella Cousins, a worker in the Inspections Branch, in an interview of 26 April 1984.
9. Moroney. He comments: 'We didn't conscript women—not much!'
10. H. John Lewis, Salisbury South Australia: a history of town and district. Investigator Press, Adelaide, 1980, p.206. This is a common recollection: 'When I first went out there the fumes were absolutely terrible working in TNT. When you walked into the building you could see a red haze hanging in the air. TNT when it's molten is a reddy orange colour and the smell was so nauseating; you used to feel so sick when you came home.' Interview with Mrs Winifred McIntyre on 30 May 1985.
11. Smoker.
12. Mellor, p.353.
13. Not two, as Ivan Southall says in Woomera, Angus & Robertson, Melbourne, 1962, p. 17.
14. Memo titled 'Material for UK progress report' dated 2 May 1947 and personal letter to Sir Ben Lockspeiser of 29 April 1947. Files 5000 part 1 folio 4A and 5031 folio B.
15. 'Rocket range work is thorough but slow', Sydney Morning Herald, 28 June 1948.
16. Minutes of the Long Range Weapons Board of Administration meeting 18 of 15 January 1948.
17. Allen, p.25, quoting from a Department of Defence Priority Sub-Committee Agenda of 14 May 1942.
18. Minute dated 8 May 1948 from CEO Evetts to CSO Butement.
19. Minute 'Allocation of Cabin Homes' dated 23 May 1951 to the Principal Administrative Officer. The list of priorities took note of the applicants' 'work value and their importance to the project' as well as domestic circumstances. File A127.
20. Donald Cameron, 'Physical and social development of Salisbury, South Australia'. Unpublished Master of Urban & Regional Planning thesis, University of Adelaide, 1979.
21. Allen, p.66. One retired AEL employee recalls buying a posthole digger for that very purpose.
22. Reminiscence of Doug Priest, a draftsman at the Establishment, in an interview of 13 July 1983.
23. Allen, p.61, quoting from a Housing Trust file of 3 July 1952.
24. Allen, p.62, quoting from a Housing Trust file of 28 Sept 1955.

4 In the firing line 1: *The Pastoralists*

SAFETY: A PARAMOUNT CONSIDERATION

The business of testing guided weapons and other aerial vehicles is intrinsically dangerous. A rocket sitting quietly on the launcher or smoothly pursuing its course may look harmless enough, but while it is filled with propellants it is potentially a high explosive bomb. When the missiles are experimental, their guidance unreliable and their performance unpredictable, this potential explosiveness can become actual in a fraction of a second.

The engineers and technicians of the Range could not avoid all risks. They understood them and to some extent were paid to take them. But Woomera was the largest land range in the Western world, and within its ambit lay country inhabited, albeit sparsely, by pastoralists and tribal Aborigines. Neither group had asked for the Range to be set up and neither benefited directly from it; but of the two the pastoralists were most at risk because their sprawling properties lay closest to the rangehead where the most activity was concentrated. The successful operation of the Range greatly depended on maintaining good relations with these scattered residents. Should a severe accident ever occur, such as a direct impact on a homestead, public opinion could turn against Woomera and force its closure or the total evacuation of everyone living down-range. For this reason, not to mention the obvious ethical imperatives, the joint project officialdom was alive from the start to the question of public safety. Enormous effort and large sums of money went into making the project's activities as safe as was humanly possible. The procedures they devised were an unqualified success. Not a single resident of the country around the Range was injured during the entire span of the project. No property was ever damaged as a direct consequence of a trial. The only report of casualties in more than thirty years came from the Manners Creek station in the Northern Territory. In 1967, during the trials of ELDO's large satellite launcher rocket Europa I, a stockman claimed to have found the corpses of three cows on the property surrounded by metal wreckage. One of the cows was graphically described as having been thrown into a tree by the blast. No bodies were forthcoming, but the Commonwealth accepted the claim and ELDO paid compensation.

THE FIRST PROPOSALS

When, in May 1946, Evetts presented his report on his first mission to Australia, he touched on briefly the possible dangers to the inhabitants of the chosen area. He believed those dangers were so slight as to be negligible. It was a matter, he said, of some hundreds of people, European and Aboriginal, being scattered over a vast domain bigger than Western Europe:

> General conclusions, backed by the opinion of every authority consulted are that no great difficulty should be experienced on the grounds of population either from the safety or security aspect. If the transfer of inhabitants and, consequently, compensation were necessary in certain cases the sum involved should not be excessive.[1]

Evetts's comments related, of course, to the original choice of a site for the Range. Had the original plan of building the rangehead at Mt Eba held good, the problem of ensuring the safety of the resident population would have been much reduced. The Mt Eba station is nearly at the limit of pastoral activity. North-west of it stretches a vast region of semi-desert and practically unpeopled land. It is true that the centre line of the Range went on to cross the Aboriginal reserves, but as we shall see in the next chapter even the opponents of the Range implicitly conceded that the inhabitants were in little physical danger: their campaign to halt the Range made little headway until they shifted ground to the cultural danger of intruding on the reserves.

The question of the safety of the residents began to loom large only when the Board of Administration took the decision early in 1947 to pull back the rangehead to Pimba. The new location was deep within the zone of pastoral activity. The first part of the Range now included all or part of no fewer than eighteen pastoral leases, and at least nine homesteads and twenty-five outstations were now within the tentative danger zone: in total, upward of a hundred people. Though as things turned out no Range activities posed the slightest risk to the pastoralists until the onset of the Black Knight program nearly a decade after the foundation, this was certainly not the supposition in the earliest days. The initial belief was that long distance trials would be beginning in a few years and therefore that many leases along the path of the Range would have to be resumed and the people resettled elsewhere. Defence Minister John Dedman had said as much in his statement in the House of Representatives on 22 November 1946.

The task of resuming rural leases was a very different proposition from compulsorily acquiring a suburban house for a new road. In their extreme isolation the pastoral properties of South Australia had evolved a self-contained, almost feudal way of life. Mt Eba, for instance, ran 17 000 sheep in a good season over 2200 square kilometres, and the homestead had its own freezing plant. In addition to the family the station employed a book-keeper, a governess, a housemaid, a cook and about thirty hands. The whole menage was presided over by Mrs Flo Crombie, a cheerful Rabelaisian woman who was awed by no one, especially VIPs from the Range. On a later occasion, Mt Eba was visited by no less a person than the Governor General, Field Marshal Sir William Slim. With some ceremony Slim and his party were ushered into the old homestead with its fortress-like walls to keep the heat out, and thence to the cool and spacious dining room at the centre. They stared in wonderment at the ceiling lined with blue-painted canvas and the vast mahogany dining-room table capable of seating a couple of dozen. Slim was a distinguished soldier who had led the 14th, so-called 'forgotten', Army to a great victory in Burma. But he was very British, patrician and somewhat stiff in manner. He made a valiant attempt to establish some rapport with his hostess, 'Well, well, Mrs Crombie, this is absolutely marvellous, marvellous. Here am I, in the middle of the desert, sitting at comfort at the head of your table'. 'My bloody oath you're not!' was Mrs Crombie's stout reply. 'My old man's the one who sits at the head of the table. You're down here'.

'Head of the Table'

Mt Eba homestead, one of many running sheep on leased Crown land in the Range area.

Another time she was visited by a Parliamentary party including the veteran Billy Wentworth. One of those present, who knew the habits of the house well, remembers:

> Mrs Crombie had a huge tray cloth with a map of Australia crocheted on it in colour. If she found her visitors congenial she would get out a kerosene box and put it down in the middle of the living-room floor and spread this cloth over it. Then she'd move it around until she found a clear space and say 'Righto, you!' and you would go over and say 'Thank you Mrs Crombie' and sign your name. It was a ritual. After the whole party had signed and left she would crochet in the names in colour. In this fashion the whole cloth was being filled in with the signatures of celebrities. On this occasion, when she had all the Parliamentarians on their knees round the kerosene box, she noticed that old Billy Wentworth was leaning against the mantelpiece just looking on, with his pale blue eyes, silver hair and red face. Mrs Crombie, piqued that he was standing aloof, went up to him, eyed him narrowly, and then commented: 'How did an old bugger like you manage to get into politics? You're so bloody old you ought to be dead!' Wentworth's mouth fell open. He said nothing; his breath was knocked away.[2]

Such were the sterling individualists who stood to lose their unique way of life, and with whom the Range authorities had to come to an understanding.

Rumours that the rangehead was to be moved back were rife among the pastoralists in February 1947. Suspecting that if this happened his property would be right in the line of fire, the Secretary of Mt Eba Ltd, J, Churchill Smith, wrote to Premier Playford late that month in slightly aggrieved tones. He felt that his Board was being kept in the dark. Improvements to the property were in view, and arrangements for future lambing had to be made soon. Please could the government make its intentions known? The Premier's secretary sought the advice of A. P. Rowe, then Chief Scientific Officer of the fledgling LRWO. Rowe replied confidentially that the rangehead would very probably be moved to a site near Phillip Ponds and that Mt Eba station would indeed be in the line of fire some 130 kilometres down-range. What was to be done about this had not been decided. Rowe could only suggest that it would probably be inadvisable 'to do more than give a non-committal reply to the Mt Eba Board'[3]—which was thereupon left in suspense for some weeks longer.

Major A. I. Wynne-Williams, Evetts's consultant engineer.

The task of investigating the safety problem was initially put in the hands of Major A. I. Wynne-Williams, a consultant engineer from MoS who was attached to Evetts's staff in Melbourne. Even as he began work on safety matters in June 1947, various plans—some practicable, others less so—were already being mooted. The simplest proposal was that the leaseholders should continue to live where they were, and be trucked or airlifted out of the area before a trial started. A variation on this was that the leaseholders should retain their runs, but new homesteads should be built for them outside the danger zone; then it would be necessary to round up only the men before a firing, and not their families as well. Wynne-Williams thought that either of these schemes would pose insuperable legal problems, especially if people refused to be evacuated. All in all, and with the possibility of expensive lawsuits for losses to life, limb and property well to the fore in his thinking, Wynne-Williams favoured a bold solution. The Commonwealth should resume the leases for all the pastoral land running for, say, 50 kilometres down each side of the centre line of the Range. It could then continue to run the Range as a single large sheep station, employing its own men. This would have the advantage that the new employees could be ordered to take cover when necessary, whereas private citizens could only be advised to do so. This approach, thought Wynne-Williams, would have the extra appeal that experiments might be carried out into the regeneration of plant growth and the prevention of soil erosion.[4]

When he put his analysis of the situation to Evetts, the latter agreed with him and in his usual incisive fashion outlined the position at the end of June 1947 to M. Hambidge, the Surveyor General of the SA Department of Lands, who also held the office of chairman of the Pastoral Board. With the professional soldier's distaste for having civilians wandering anywhere they might get hurt, Evetts strongly favoured acquiring the leases and clearing the area. Everything would then be neat and tidy. A pastoral officer could be appointed to manage the grazing activities of the Range and its workers. No women or children would be in the area, and Commonwealth employees could be relied upon to do exactly as they were told. There would be no risk of belligerent pastoralists refusing to take cover. Security would be improved too, because the pastoral staff could be given the job of reporting any strangers. The venture should be viable economically because the overheads must be smaller than when the area was supporting eight separate homesteads. He also liked the idea of conducting some pastoral experiments. These were persuasive arguments and Evetts marshalled them with skill. What he did refuse to consider was leaving the existing leaseholders in residence, even with bomb-proof shelters to retreat to. 'Examination of this method', he said, 'shows it to be unworkable'.[5]

Evetts argued hard for his radical solution, but it foundered on the usual rock: money. Resuming all the grazing leases would cost the very large sum of £800 000. (Some idea of its purchasing power can be gained from the fact that in the same year the government allocated £872 000 to found the entire Australian National University!) As soon as Senator Armstrong, the Minister for Munitions, heard about the scheme he wrote a dusty letter to the Long Range Weapons Board pointing out that '*a* project of this kind would require much investigation before it could be considered' and also mentioning the 'risks associated with carrying on a pastoral industry in arid country'.[6] Clearly Armstrong did not rate highly the pastoral abilities of the LRWO men. What he suggested instead was an interdepartmental committee to look into the best way of making the land available, taking due note of the existing pastoral activities, the technical requirements, and the usual trilogy of safety, security and economy.

Senator Armstrong, Minister for Munitions in the Chifley government. (PA)

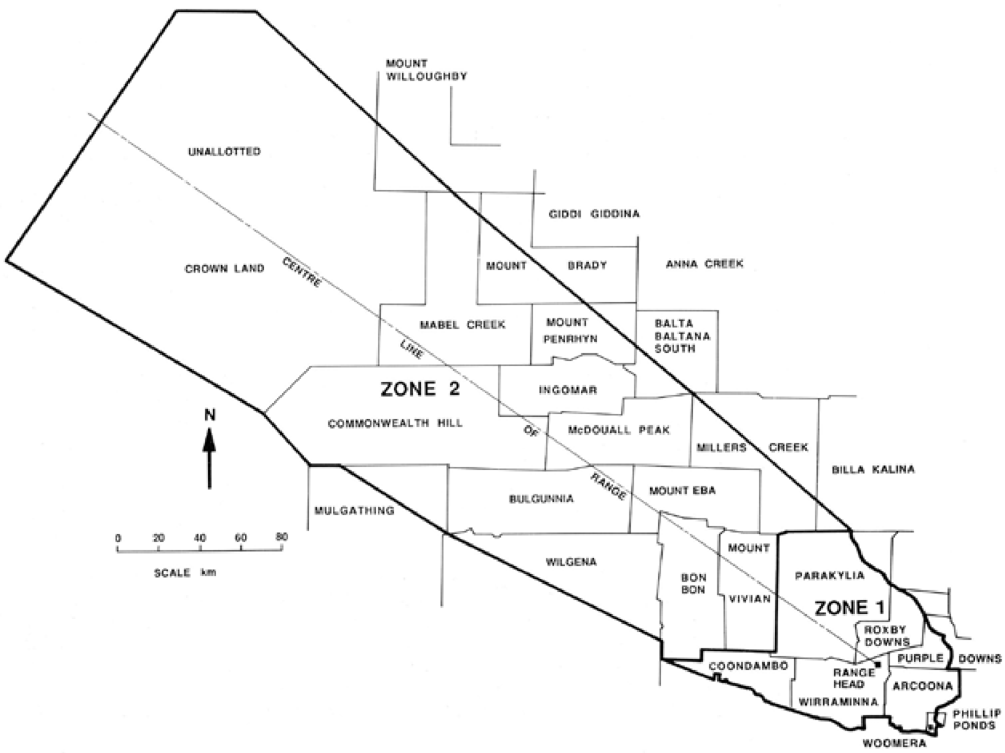
Meanwhile the pastoralists had been taking stock of their own position. All sorts of rumours were flying around, fuelled by reports from the apprehensive citizens of Port Augusta that an endless convoy of trucks filled with heavy equipment was grinding through their town by day and night. It was said that the authorities were now planning a town of four thousand inhabitants, not a village of four hundred. An invasion of the outback on this scale was unprecedented. Questions were asked in the South Australian Parliament and Premier Playford did his best to assure the House that for the moment only 'a temporary withdrawal of employees during the firing' was being contemplated. Despite his assurances, and the usual uncritical lead from the local media that mere sheep must not hinder imperial defence plans, the fear persisted that some of the best wool-growing country in the State was under threat. The recent seasons had been excellent, and if the stations were closed the value of the clip might drop by half a million pounds a year.[7]

One of the most concerned was Byron MacLachlan, the leaseholder of Commonwealth Hill, the most westerly property of those likely to be affected. During his outback tour Evetts had discussed the plans for the Range with him, and when MacLachlan correctly divined that Evetts favoured resuming the lease on his property, he lost no time in discussing the matter with a lawyer friend, Bob Irwin, who was a partner in the Adelaide firm of Piper, Bakewell & Piper. Between them Irwin and MacLachlan decided it was time for the leaseholders to develop their own point of view, and Irwin's firm was retained to canvass the opinion of the other leaseholders and prepare the case. The submission to LRWO took the form of a lengthy memorandum. Its object was, it said, to provide 'a basis for continuance of present pastoral activities consistent with carrying out the proposed Long Range Weapons Project'.

Acting as the representative of most of the leaseholders affected, Piper, Bakewell & Piper submitted detailed proposals from each one separately but summarised the main points on which all were agreed. The pastoralists' requirements were far from onerous. They were, as they put it, 'most anxious to carry on their pastoral activities whilst co-operating fully in the carrying out of your project'. The key points were that no women or children should live 'in the range' except with the consent of the Organisation; that the homesteads of six leaseholders should be rebuilt outside the Range zone; that a telephone warning network should be established between the homesteads and the Range headquarters and due notice of trials given; that compensation should be paid for damage by fire or otherwise (though even here 'all concerned are prepared to reconsider this matter if your Organisation feels any difficulty about it'); and that the leaseholders or their employees were willing to be appointed Range Overseers and 'to consider any other conditions or stipulations which may be thought necessary'. It is hard to see how they could have been more accommodating, short of actually volunteering to move out.

While the committee was digesting this document and otherwise considering the problem, Evetts produced for its benefit his own appreciation of the situation as he saw it in January 1948. He started by defining, very arbitrarily, a 'danger zone' reaching 48 kilometres to each side of the mid-line, or azimuth, of the Range and extending outwards for 480 kilometres. (More accurately, of course, the danger zone was fan shaped, with its apex at the rangehead; but anticipating that the test vehicles would contain a break-up system, Evetts thought it reasonable to make the zone a long rectangle.) Within this area lay all or part of some twenty leases and nine occupied homesteads. Evetts remained adamant as ever that only LRWO employees should be on the Range during trials. Hair-raising legal complications might arise if people were left in residence:

> Questions arise on the legal aspect of fatal or lesser accidents to any of the occupants of the homesteads or other persons who might be in the Zone. There appears to be no precedent for the deliberate landing of lethal missiles at random in an inhabited area, and the nature of the experimental work to be carried out precludes the accurate forecasting of danger areas and times as is done at practice and proof ranges.[8]



The 480 kilometre danger zone' defined in 1948 and the twenty pastoral leases included. Only the small Zone I was affected by the early trials.

The alternative of leaving people in place, he argued, would mean strong and expensive shelters for everyone or, if whole families were to be moved out each time, special transport arrangements and elaborate accommodation well beyond the Range. The question of recompense for disruption to pastoral activities would surely come up. How could the mustering, crutching, shearing, dipping and the other routines of pastoral life possibly be fitted around every program of trials? The expense would be enormous and the administrative problems were horrible to contemplate. Clear the Range, argued Evetts. Any other course was practically impossible.

The committee set up by Armstrong met twice, in January and February 1948, and reported back to him soon after. The product of its deliberations was disappointing. It emerged that the committee's chief manoeuvre had been to make the problem more tractable by restricting attention to the area likely to be affected by the very first work of the project, which it called 'Zone 1'. Zone 1 was only a small fraction of the 480 kilometres range of the original plan. It amounted to no more than the rangehead itself, the new bomb ballistics range, the Technical Area, the village site, and a danger arc 48 kilometres wide forward of the rangehead. What the Commonwealth should do, advised the committee, was to lease all of Zone 1 (which comprised parts of eight leaseholdings) from the South Australian government. No homesteads lay within this Zone. The committee saw no virtue in Commonwealth involvement in pastoral activities. That should be left to the leaseholders except that the Range Superintendent should have the final say over what happened in the Zone. All the other matters should be resolved by 'negotiations with the present lessees'.

The thread which ran through the committee's determinations was its anxiety to avoid the necessity of buying pastoral leases. It failed to address the main issue squarely and it certainly did not, as its terms of reference required, find a solution. It merely dropped the problem into the lap of the Range Superintendent, who in principle at least was now expected to carry alone the responsibility of avoiding accidents.

While on a visit to South Australia soon afterwards, Senator Armstrong took the opportunity of meeting the leaseholders and their representatives. Accompanied by Evetts, Hambidge, Irwin of Piper, Bakewell & Piper and fortified with a thorough briefing based on the interdepartmental committee's report and the Irwin Memorandum, Armstrong met the pastoralists at the elegant old South Australian Hotel on North Terrace in Adelaide on 23 March 1948. Naturally everyone wanted to know in general terms what the project would be doing, but most of the discussion centred on the proposals they had put forward through their solicitor. In particular they were eager to hear what the Minister thought of their proposal that certain homesteads should be demolished and rebuilt out of the area. Here Armstrong temporised, saying that 'this would be a very difficult task' and that he thought 'it was not at all necessary that any homestead be moved' at least for the time being. He did promise that a communication link would be established between the rangehead and the homesteads, and sufficient warning would always be given so that women and children could be moved out of the area when necessary. In qualifying the 'danger area' the Minister explained that only an 'area of impact' needed to be cleared, such as the relatively small bombing range. Hardly any of the land which would merely be overflown would have to be cleared, said the Minister, but the final decision must rest with the Range Superintendent. Indeed, the Minister opened with the rather chilling remark that 'one of the most important problems was that of protecting the Superintendent of the Range from any criminal liability as a result of fatal accidents'. Whatever the legal status of this possibility it did not appear to have cast a shadow over the proceedings, for after some forty minutes of discussion the meeting closed with expressions of co-operation on all sides.[9]

Lt Col Geoff Solomon. He was the Acting Range Superintendent.

The following month Evetts, who by now had resigned himself to the permanent presence of the leaseholders, asked the Range Superintendent to interview them all and produce a workable safety plan for Zone 1. The Acting Superintendent, Lt Col Geoff Solomon, got this job. When his plan appeared that September, it defined responsibilities on both sides. Leaseholders should be asked to submit each year the periods of shearing and crutching, and should also be asked to ensure that no one was left in any nominated danger area. For his part, the Range Superintendent should arrange matters so that the rhythms of pastoral life were not disrupted. He should issue warnings of trials two months, one week and then forty-eight hours beforehand and should help in evacuating people from the danger zone and find them shelter In the village 'if practicable'.[10] The report was silent on how exactly evacuation should be managed, especially if people refused to go, and where the ultimate responsibilities lay.

Fortunately the plan was never subjected to a serious test, for two reasons. First, Range operations did not extend out even to the limits of Zone 1 for some years and did not come anywhere near dwellings. Second, the joint project authorities continued to be on excellent terms with the pastoralists, whose public pleasures had hitherto been restricted to the Kingoonya Races and the like. The growth of Woomera brought roads, doctors, communications, social life and a little bit of urbanity, and members of families like the Mudies, the Morleys and the McTaggarts became familiar sights in the village. In return for a share in town life they were willing to put up with no little inconvenience, as when the Roxby Downs leaseholder, David Greenfield, abandoned his Boundary Wells outstation in January 1953. By moving his men to a new location on the edge of Zone 1, he left the Range area clear for about 56 kilometres. Another factor helping the good relations was that when it came to appoint Range Overseers the Establishment made a series of wise choices, starting with RAAF officer Colin Bell. The personable Bell patrolled about the Range in a light Auster, visiting stations—Arcoona, Roxby Downs, Yudnapinna, Mabel Creek and the rest—on a loose schedule. This little plane was well suited to reconnaissance work and Bell spent much of his time bumping through a heat haze down close to the saltbush to make sure no one was in the danger area. The Overseers—Peter Campbell and then Tony Jay took over from Bell—were diplomatic men able to deal with awkwardnesses before they grew serious, and they and their families were content to resign themselves to having a job that was more a way of life. Tony and Dulcie Jay's house at Woomera, where they lived for twenty-six years, was much used by pastoralists and their families on their way to and from their properties. The hospitable Dulcie Jay would quite frequently get up in the morning to find bodies lying on their swags in front of the fire, or in hot weather out on the lawn. In return the Jays received calico bags containing deliciously flavoured saltbush mutton, and Erwin Greenfield of Bosworth Station would bring in eggs and cream to exchange for vegetables and flowers.

Colin Bell, the first Range Overseer.

HOMESTEAD WARNING

By 1952, when longer distance trials were just appearing on the horizon, even the idea of temporary evacuation had been tacitly abandoned. The station folk themselves now saw no reason to be moved, and made it clear to the Overseer that they were game to take any reasonable risk. Having grown used to having a rocket range for a neighbour they treated its activities with casual good humour, and few of them seemed bothered that the promised telephone link had not yet materialised.[11] The reason for the delay was partly that the Range developed much more slowly than anticipated in 1948, and partly because of uncertainty about whether to install a phone or radio link.

In the course of writing his safety report for Zone 1 in 1948, Solomon had asked all the pastoralists inside the Zone what system they preferred, and found that everyone wanted an ordinary telephone line rather than radio, which, he observed, 'at the moment seems to scare them'. Solomon drew up the pros and cons of radio and line links in his report, noting that a PMG radio telephone network based at Broken Hill was already in use and included the nearby Andamooka opal fields. He recommended taking advice from the PMG.[12]

Discussions early in 1949 between PMG engineers and LRWE concluded that only a phone warning system would be fully reliable. However, time was pressing and both materials and manpower were short, so the line network would have to be supplemented by radio, at least in the early stages. The system used at Broken Hill was not favoured: it was an experimental HF service intended to communicate with distant outback stations, and relied on reflection from the ionosphere to achieve the range. A VHF system was likely to be more reliable, and the PMG agreed to buy eleven VHF/FM transceivers at LRWE expense to try them out. Working into aerials mounted at least 15 metres high, the transceivers should have a range of 70 to 80 kilometres, but this depended on the terrain and the PMG wanted to test them thoroughly before handing them over to LRWE.[13]

In the June of 1949 Overseer Colin Bell and PMG engineer Ted McGrath, who was responsible for radio telephony in South Australia, did the rounds by jeep and the little Auster of the six station homesteads in Zone 1 and another ten further out, stretching from Arcoona to McDouall Peak some 190 kilometres down-range. While Bell discussed the safety procedures, McGrath had a look at their communications. Some homesteads already had PMG phones, and most had also set up their own phone links to their outstations, using single galvanised steel wires strung untidily on wooden poles, and with the return circuit through the ground. Some lines simply used the top wire of the boundary fence. Losses on steel wire are high, so reception on some lines would be too faint and noisy, but McGrath thought some of these links might form part of the system. Otherwise it was radio, and McGrath succeeded in persuading the pastoralists to use the radios if provided, and to keep the batteries charged and perhaps do other minor maintenance.[14]

By August 1951 some of the VHF radios were in place and being tested. The base station was a small hut half way between the Tech Area and Koolymilka, on the road to Range E: it was called Ashton Hill, although actually it was on a stretch of flat gibber plain. Transceivers were installed at Parakylia and Coondambo, the most distant of the Zone 1 stations. By then the other four Zone 1 homesteads—Arcoona, Roxby Downs, Purple Downs and Wirraminna—had been linked to the Woomera network by temporarily using the pastoralists' own single wire lines. This would not do for the more distant Parakylia and Coondambo, so for those it was either the radio or expensive high grade lines. But by the end of 1951 it had become clear that the experimental radio link would not be good enough unless much higher aerials were provided.[15] These would probably have cost as much as wire lines and ordinary phones, and even then could not match simple lines for reliability, ease of maintenance and security.

Even so, more than a year passed before the VHF radio scheme was finally abandoned. On 2 February 1953 the Board of Management agreed to spend £16 000 on lines and standard telephone sets for all six stations in Zone 1 and for another four in Zone 2: Mt Vivian, Bon Bon, Millers Creek and Billa Kalina. (Mt Eba, also in Zone 2, already had a first class link.) This would cover all properties up to 120 kilometres down-range.[16] By now thoughts were turning again to trials that would extend outside Zone 1: the Red Rapier expendable bomber project was then on the CUKAC program, although the full scale concept never came to Woomera.

Some of the links were made by upgrading the existing single steel wire lines run by the pastoralists themselves, but for others, including spur lines from near the end of the Mt Eba route to Mt Vivian and Bon Bon, PMG linesmen built new lines, using steel poles recovered from the old camp of the No. 1 Line Construction Project Squadron (1LCPS) at Koolymilka, and single copper wires with earth return. Most were connected to the high grade pole routes built for the Range by 1LCPS. All this work was finished by the end of 1953.

Many of the pastoralists got a much better general phone service along with the warning system, and a few later had the luxury of automatic dialling. They could use it privately without rental charges, as the Department of Supply footed the bill. There were queries about this at the time, but really it was a fair bargain. After all, the department needed the warning system for safety's sake and the pastoralists did many favours in return: diligently reporting events such as shearing routines, finds of missiles lost after impact and perhaps suspicious strangers on their properties. And they had been promised the telephone communication link back in 1948 by the Minister himself, without any implication that they would have to pay for it.[17]

The network was extended in 1958-59 when the shelters were built and, as we shall see shortly, finally reached down-range as far as Mabel Creek and Commonwealth Hill at the limit of the pastoral leases. Most of the extension eventually used line telephone as well but HF radio was used for some, including temporary links—not VHF, as had been formerly tried in Zone 1, as the distances were much too great. And in 1966-70 radio was used for the northerly firings of Europa. Homesteads in the first stage impact region were warned by a radio telephone network based at Alice Springs that the PMG had recently installed, and all WRE had to pay was the rental.[18]

THE SHELTERS PROPOSED

After the flurry of concern about the physical safety of the pastoralists in 1948, the whole question went into abeyance for several years. All the activities of Woomera were concentrated into the area just around the 600 workers themselves. Only with the start of the Black Knight program, for which the first RAE specifications were received by Australia in July 1955, did the issue come up again.

As Chapter 21 describes in detail, Black Knight was a powerful research rocket designed to take a re-entry head high into space and then to project it back down into the atmosphere at a great velocity. Black Knight had a trajectory shaped like a hairpin on end. Its impact zone was planned to be only 80 kilometres down-range, even though it climbed ten times that distance into space, and its remnants could fall anywhere in a circle with a radius of 30 kilometres. Such an impact zone contained portions of five properties, one homestead and two outstations. Another three homesteads lay on its perimeter.

The author of the first paper on Black Knight's requirements at Woomera observed almost as an afterthought that, 'no personnel unconcerned with the firing should be allowed in the impact area,'[19] but this did not excite any immediate concern for the pastoralists. Safety matters were discussed, and in detail; but they were limited to the type of self-destruct system, the layout of the launch site, how to restrict the size of the impact zone and other technical matters. It was not until a year later, in mid-1956, when Controller Harold Brown was seeking approval from the Department of Supply on the safety arrangements for Black Knight, that the pastoralists came under scrutiny again. In his submission[20] Brown pointed out that while most of the Black Knights—about 80 per cent of them—would fall in the impact area and half of the remainder might be cut down early in flight near the rangehead, this still left 10 per cent falling elsewhere. An impact predictor (a type of computer) could be used to show where the rockets were likely to fall while they were still in flight, but it was an inaccurate device and might mean one in three Black Knights was being destroyed in the air because of false information. Brown knew this was intolerable, because the value of a completed Black Knight trial far exceeded any possible damage it could do short of killing or injuring someone. Statistical analysis showed that even in the worst case the risk of injury to a person and damage to a building was so very low that it should be accepted without special measures. The alternative was shelters for people and additions to the homestead warning system. Since no one was speaking any longer of evacuation as a real possibility, the only question left was: to shelter or not to shelter?

On this simple question the Board of Management quickly reached a decision, determining in July 1956 that both shelters and a warning system should be available to every homestead in the Black Knight impact area. Controller Brown was also asked to have a plan prepared to provide for the security of other homesteads outside this impact area. Perhaps the Board had been swayed by its chairman, Alan Butement, who had the erroneous impression that shelters had been promised in March 1948. In fact this was not so. A warning system, as well as the evacuation of 'danger areas' had been promised, but no one had said anything about shelters. The subject had not come up at all. Be that as it may, the Board had set its policy. All the residents in the impact area would be protected by shelters strong enough to resist flying debris, though not a direct hit. In addition, around each occupied place an imaginary circle was to be drawn; and any missile whose track suggested it was misbehaving and was about to enter a circle was to be cut down.

This last proposition drew an immediate reaction from WRE. The trouble was that the rather imprecise impact predictors could not give the Flight Safety Officer very exact information if a rocket began to veer off course. In addition certain data about Black Knight's performance were simply not available. To allow for this imprecision the circular 'islands' with homesteads at their centres would need to be up to 24 kilometres across, and together would form an almost continuous band across the Range, leaving insufficient room for an impact area. The alternative was an impact area on the far side of the belt of homesteads, but to reach it the missile would have to cross a 'homestead island' and thus be cut down anyway.

From Woomera, the Superintendent, Captain Jack Newman, added a little fuel to the fire when he reminded Salisbury at the end of August of his earlier advice that 'some uneasiness was growing amongst station owners and managers . . . in regard to possible danger to their wives and families'. Newman had spent a good deal of effort winning the pastoralists' confidence about the innocuousness of the Range's activities. Now it was common knowledge that shelters were being planned. 'It will be impossible,' he said, 'to convince the pastoralists that the risk is small if they see a large expenditure taking place on shelters'. It was inviting people to worry about the itinerants who would not be sheltered and about the adequacy of the shelters themselves.[21]

It was time to have another look. At a further meeting on 4 September 1956 the Board dropped the 'homestead island' concept as unworkable. It came up instead with a plan of total protection. Every homestead, shearing shed and outstation should be supplied with a shelter of massive reinforced concrete, giving the 160 or so residents security against even the tiny possibility of a direct hit.

But when WRE estimated the cost of these facilities at six or seven hundred thousand pounds, a very large sum at the time, there was a good deal of backpedalling. The British, in the shape of their UKMOSS representative Dr W. H. Wheeler, thought that the pastoralists were in no greater danger than anyone living near the flight paths of an airport. The business adviser to the Minister of Supply wondered if heavy concrete bunkers would give the public the idea that the risk was much greater than it really was, so creating a 'fear neurosis'. Butement, the chairman, suggested that 'slit trenches which could be provided cheaply' might be a good compromise. Considering how much concern had been expressed about the pastoralists' welfare, this struck WRE as a strange suggestion. Using even a well designed shelter was bound to disrupt the life of the stations. The pastoralists were well disposed to the activities at Woomera, but how long would their sympathy last if they were asked to crouch in a slit trench, with all its flavour of a World War II 'air raid imminent' warning? Nevertheless, as Controller Brown later advised his deputy, then in London, the Board's eventual conclusion was that 'warning with little more than slit trenches should be sufficient and should meet political requirements if the case was put properly'.[22] Fortunately in the end WRE's more sober and factual assessment in favour of mounded shelters to give only protection against flying debris carried the day, although WRE erred in assuming that only the Black Knight program, and not the trials of the unguided high altitude rocket Skylark, needed to be taken into account in deciding on the number of shelters.[23]

Armed with this information the Minister for Supply, Howard Beale, sought the endorsement of the Cabinet for the new safety precautions and on 5 July 1957 he addressed a gathering of pastoralists at the South Australian Hotel, just as his predecessor, Senator Armstrong, had done. Beale assured his audience that, despite the costs of destroying a missile in flight, if one strayed outside the uninhabited impact zone the break-up command would be given if it looked like threatening an unprotected place. The Commonwealth would pay for blast-proof shelters, each one made of thousands of sandbags piled on a tough semi-circular steel frame. It would also extend the telephone warning system.

Thus the political commitment was made. More than twelve years had gone by since Evetts in his search for a Range site had said that 'no great difficulty should be experienced on the ground of population' and it was nine years since the pastoralists had first presented their case to Senator Armstrong.

A typical homestead blastproof shelter. After long arguments about the expense and the psychological effect, nearly fifty were built to protect the station staff.

THE SHELTERS CONSTRUCTED

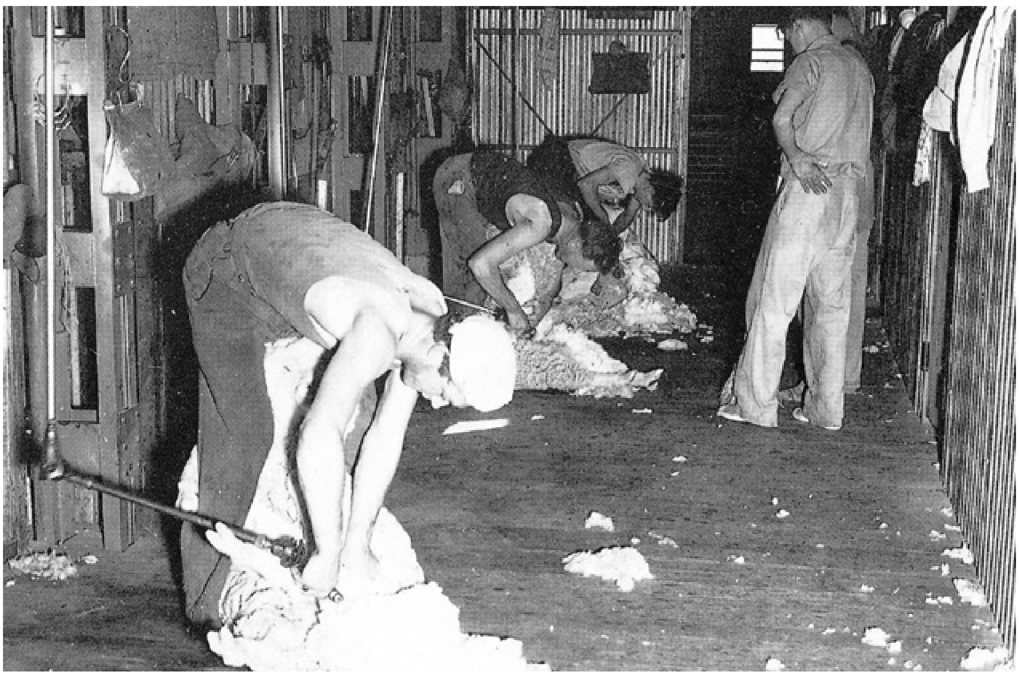
In August 1957 WRE prepared to install the shelters and supplement the existing warning system. It requested the Board of Management to allocate £30 000 for shelters at six homesteads and eleven property outstations, and a further £8000 for connecting The Twins homestead to the telephone network.

Despite WRE's earlier belief that neither Skylark nor the Blue Steel trials called for special precautions, Skylark certainly figured in the August 1957 submission; in fact it was the reason why shelters were ordered for two homesteads in addition to the original list of four. As explained in Chapter 20, Skylark's trajectory was set by the position of its launcher, adjusted after analysing the wind speed and direction at various heights. Once in flight it had no more guidance than a Guy Fawkes rocket. Normally it landed 160 kilometres or so down-range, and its impact point could not be set within 30 kilometres or even more. Skylarks started to be fired before the shelter construction began. Still, the shelters were all in place before much of 1958 had passed, and with their completion the warnings from the rangehead were increased to three, with a final 'take cover' coming fifteen minutes before a firing.

Over the next few years the number of shelters was much increased. Higher altitude flights for Skylark, and the trials of the Blue Steel air-launched missile which flew over several properties and had its impact area on the McDouall Peak station, eventually led to all the homesteads in the enlarged trials area being given protection. Later on most of the outstations too were included, following an incident in 1958 when a Skylark landed well outside its impact area, not far from a manned outstation on Wilgena station. The workers there had not been alarmed, but they wanted to know why they had had no warning.

All that remained now was the question of the woolsheds, which were occupied intermittently at shearing time. Thirty to forty men lived in them for several weeks on end, working under a contract which contained the usual penalty clauses in the event of delays. Transporting the shearers to the nearest shelter could have proved expensive for the Commonwealth, so in the end it was prudent for the Board to pay for shelters at the woolsheds too.

In the final count no fewer than forty-eight places were protected by shelters, provided at a cost of £127 000. With a few minor exceptions every place of habitation on the Range, whether temporary or permanent, was physically protected and was connected to the warning system. The latter included sixteen homesteads as well as sirens at some outstations. For a total sum of £155 000 the promises made by the politicians had been kept. It had not been cheap, except by comparison with the original scheme of resumption, and the money had bought protection for a much bigger area of the Range than Evetts had



Shearing at Arcoona Station.

envisaged in 1947. The pastoralists themselves were very happy with their shelters and even more so with their better phone service. But was it all really necessary? Experience suggests it was not.

It is hard to say how much the shelters were used—for their official purpose, that is to say. At first some at least of the residents dutifully retreated into them. Others quickly got transformed into games rooms or hay stores, and one was repaired regularly by WRE because cattle kept damaging the entrance. When Black Knight began to be launched in the hours of darkness, watching the fiery trails slashed across the velvety sky by the re-entry head as it plummeted to earth became a popular activity all over the outback. By this time practically no one was bothering to take cover, although one of the later trials caused consternation at Mt Eba. Mrs Crombie described the occasion to Dick Durance, the Range Superintendent, in her inimitable way:

> They sent us a notice, Black Knight was going up. First it was seventy-two hours then twenty-four hours, and at last they told us to take cover in the shelter. 'Course, we weren't in it. In fact the whole household was standing on top of it to get a good look. The rocket went up in the dark but it produced flashes every few seconds so you could see it climbing. It went up and up and everyone was enjoying the show. Then it turned over and began to come down. All the stockhands thought it was falling on them, and it did fall only a few miles away. I turned round to speak to the men and there wasn't a bastard there, Dick, not one bastard, and I was washing underpants for a week after![24]

'Began to come down'

By 1962 practically all the Range dwellers had grown casual about the warnings and often continued to work right through them. The sense of urgency had been dulled by the sheer frequency of calls during the busy season at the Range: there might be one every day for the closer properties. Some homesteads let it be known that they didn't take calls after 1 p.m. whatever the reason; others simply left their phones off the hook. The most distant homesteads might get only two calls a year. Captain Newman at Woomera learnt from conversations with the station managers that they did not tell their staff about a prospective trial because if a spent missile was later found on the property it was enough for the manager to say that he knew all about it and there was no cause for concern. Which, by any reasonable standard, there was not. It is worth bearing in mind that none of the instrumentation sites on the Range, including the large Mirikata complex just beyond The Twins homestead, had any provision at all for sheltering the staff. The biggest continuous effect of the down-range safety provisions was the frustration it caused at Range headquarters. For each trial upwards of a hundred people might be deployed over 200 000 hectares, each of them costing three times as much to maintain at Woomera as in a capital city. Yet regulations were invariably followed to the letter, despite the inordinate expense and irritation of a delayed trials program.

Notes and Sources

1. I. F. Evetts *et al*, ‘Report by the mission to Australia in connection with guided missiles (May 1946)’.
2. Anecdotes of the Mt Eba household told by Brigadier Dick Durance in an interview of 5 December 1983.
3. Letter dated 28 February 1948 from CSO to M. A. F. Pearce, Secretary to the Premier. AA MP1748 file GW/P/3.
4. Memo dated 23 lune 1947 from Chairman of the Pastoral Board to the Director of Lands. AA MP1748 file GW/W/3.
5. Letter dated 30 June 1947 from CEO to Surveyor General C.M. Hambidge. AA MP1748 file GW/W/3.
6. Letter dated 25 August 1947 to the Board of Administration. AA MP1748 file GW/ L/6.
7. See, for example, the thorough coverage in the *Advertiser*: ‘Rocket site assurance’ (26 November 1947); ‘Rocket site anxiety’ (4 December 1947); ‘Rockets and sheep’ (editorial of 5 December 1947).
8. Report dated January 1948. AA MP1748 file GW/L/6.
9. The account of Armstrong’s meeting with the pastoralists is drawn from a report dated 23 March 1948. File SA5268/1. No one bothered to insist on a formal agreement and nothing was put in writing.
10. Appendix B of Minute from Acting Range Superintendent to CEO Evetts. File SA5268/1 folio 44. Solomon has since commented on this plan: ‘I guess it was a fairly sketchy affair. Bearing in mind the conditions at the time it could have been little else’. (Letter of 16 March 1985).
11. Some lived in blissful ignorance of the activities at Woomera. Peg Bell, Colin Bell’s widow, recalls: ’The men had a good idea of what was going on but I don’t think the wives were considered important enough to be told. When Sputnik was put up it was exciting and we could see it in orbit. One of the wives said to me, “I suppose the Range has done something at last!” ’ Reminiscence of Peg Bell at an interview of 18 October 1983.
12. File SA5268/1 folio 44.
13. Minute from PMG Melbourne. See also notes on discussion between E. P. McGrath PMG and E. C. Marks LRWE. File SA5043 part 1 folios 77A and 77B.
14. Information from E. P. McGrath in a telephone interview of November 1986. See also Minute of 14 November 1951 from R. A. Foord. File SA5043 part 4 folio 638A.
15. Minute from Acting Chief Superintendent LRWE to Controller LRW in Melbourne. File SA5043 part 4 folio 650Q.
16. Minutes of Board of Management meeting 37 and submission for Item 558. The Board also included The Twins, but subsequently this was deferred when it appeared that a proposed line to Emu Field for the atomic bomb tests might also serve The Twins.
17. File SA5043 part 4 folio 638A.
18. WRE Progress Report January-June 1966.
19. Unpublished UK MOD data.
20. Submission dated 27 June 1956 to the Board of Management. File 5411/8/1 part 1.
21. Memo dated 29 August 1956 from Superintendent Range to Controller WRE. File 5411/8/1 part 1.
22. Telex dated 3 October 1956 from Controller WRE to Deputy Controller R. W. Boswell in London. File 5368 part 1.
23. Memo dated 28 February 1957 from Controller WRE to the Chief Scientist. File 5268 part 1.
24. Durance. The Black Knight in question was one of the Dazzle series, which followed an unexpected trajectory.

Nomadic Aboriginal women and baby in the Petermann Ranges, 1939. (Dr C. Duguid)

5 In the firing line 2: *The Aborigines*

EARLY CONCERNS

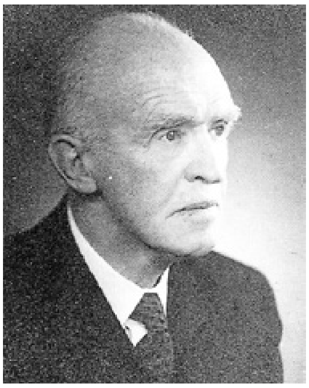
Though it was a controversy slow to ignite, the likely impact of Range activities on those Aborigines still living a tribal life in the Central Aboriginal Reserves eventually gave rise to a bitter debate in South Australia. Between August and November 1946 Adelaide's morning newspaper the *Advertiser* printed more than thirty letters and editorials on the subject, and the radio station 5KA devoted one of its popular 'Adelaide Speaks' debates to the topic 'Should Rocket Bomb tests be held in Central Australia?' To a lesser degree this concern was reflected interstate and even overseas, and a number of passionate pleas found their way to local politicians and to federal Ministers in Canberra. A one-act play, *Rocket Range*, had a brief run at Sydney's New Theatre the following year: it was by Jim Crawford, a Victorian communist, and put the issue as a simple expropriation of Aboriginal lands.[1]

Some of the protests were on purely pacifist grounds. After all, it was barely a year since the horrifying destructive power of the atom bomb had been demonstrated at Hiroshima and Nagasaki. Some Australians believed passionately that having just emerged from one war their country should not be arming itself expensively for the next. Rather it should be supporting the cause of world peace through UNO, the newly formed United Nations Organisation. A Quaker, A. K. Ashby, objected not only to the nascent Range but to the Salisbury base itself as a centre of militarism—a complaint which came several years too late, given the base's previous function. Another correspondent, C. P. Mountford, tried to combine the causes of the Aborigines and pacifism by drawing a contrast, no less potent than partisan, between the native culture with its 'kindly and well balanced laws' and the European military invasion with its 'abuses and cruelties' which in his opinion was giving that culture its death warrant.[2]

We recall that the earliest discussions in Britain about a possible missile range in Australia were secret, and in neither country did they come to the public's attention. The first hint came in October 1945 when William Coulson, the representative in London of Australia's Department of Munitions, returned to Australia to discuss Sir Alwyn Crow's unofficial approach. Brief reports then appeared in the press to the effect that a 'rocket fuel power research station' was to be set up in Central Australia. At first the government declined to comment, but on 1 November 1945 the Minister for Defence, John Dedman, announced that a British team would be visiting Australia soon to discuss the establishment of a long distance weapons range.

We have seen that Evetts's proposals for siting the rangehead at Mt Eba had already been accepted tentatively in Britain by the time the Commonwealth Defence Science Conference ended on 15 June 1946. Some whispers of this acceptance had found their way into the Sydney and London press as early as May, although formal agreement by the Australian Cabinet did not come until months later, on 19 November. Then Sir Alwyn Crow, Director of Guided Projectiles at the Ministry of Supply, held a press conference in London on 18 July; and soon afterwards some clearer details of the Evetts report were published in a story which was taken up by the Australian press on the twentieth. According to this, the mission had found 'an extensive area free from human habitation', though much further study of the report would be necessary before recommendations could be submitted to the British and Australian governments.[3] Two days later, after local geographers had been quizzed, the Adelaide *Advertiser* published a description of the huge region in the centre and north-west of the continent, wherein the mission was said to have found what it was looking for: a waterless wasteland six times the size of the British Isles, more or less unpopulated except for a few nomadic Aborigines. This impression of a yawning void was slightly modified by the more cautious tone of Professor Cleland, of the University of Adelaide, who pointed out that all the interior of Australia was peopled to some extent. He added the observation, by no means redundant at the time, that, 'the natives would have to be considered as much as the settled inhabitants'.[4] Still, even the most partisan found it hard to argue that there was much likelihood of anyone's being hurt by an unarmed rocket. On the generally accepted figures, each inhabitant of the region had an average of about 400 square kilometres of desert to himself. It must have seemed improbable—and especially so, perhaps, to the visiting Englishmen—that anyone was going to object to a range cutting diagonally across this barren and uninviting territory.

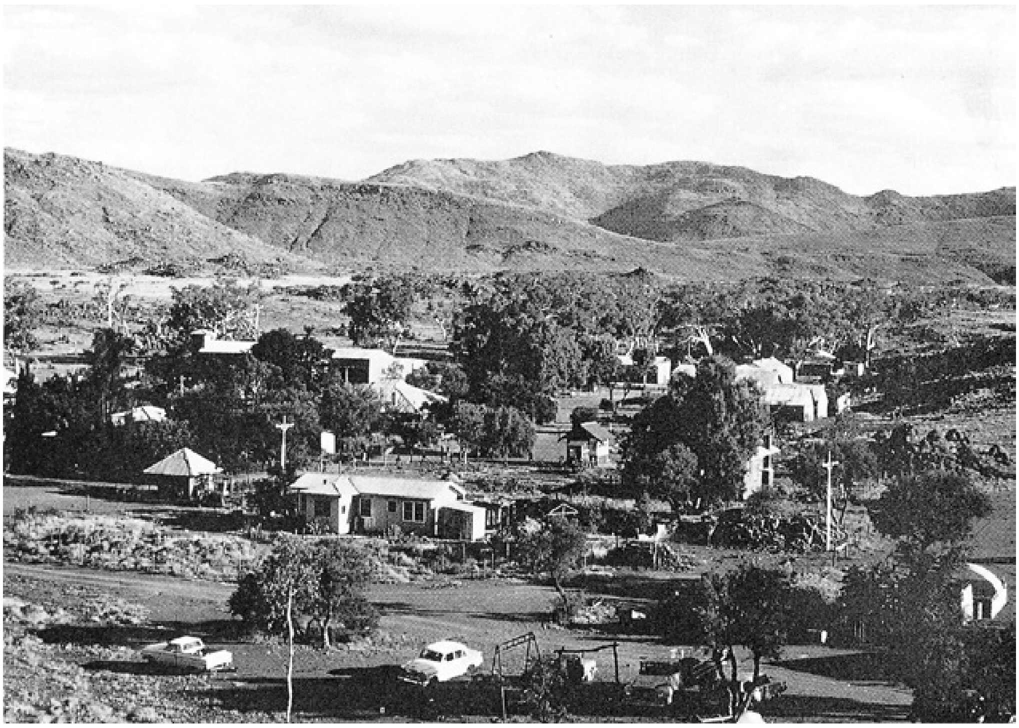
ENTER DR DUGUID: HUMANITARIAN OR COMMUNIST DUPE?



Dr Charles Duguid, Adelaide surgeon, author, lay preacher and tireless champion of Aboriginal rights. (Mrs P. Duguid)

But this is not how matters appeared to the man who soon emerged as the most formidable figure in the controversy: Charles Duguid, OBE, MA, ChB, FRCS, FRACS, an Adelaide surgeon, author, and well-known supporter of Aboriginal rights. Duguid's career, as recounted in his autobiography, *The Doctor and the Aborigines* (which won a Princeton University Best Book award)[5], had been an eventful and useful one. The son of a teacher and of a doctor's daughter, Duguid was born at Saltcoats on the Firth of Clyde, Scotland, in 1884. After studying medicine at Glasgow University at the turn of the century, Duguid emigrated to Australia and in 1914 settled in Adelaide. His first book, published in 1917, told of his grim experiences as a doctor on campaign in Egypt and Palestine with the 3rd Light Horse Regiment. Later he won the considerable honour of being appointed a lay Moderator of the Presbyterian Church and in 1937 helped to found the Ernabella Mission to the Pitjantjatjara tribe in the Musgrave Ranges. His idea of what the purpose of a mission should be was not the traditional one: he thought it should act as a 'buffer-station' to cushion the cultural shock as stone age tribesmen came into contact with the twentieth century, and missionaries certainly should not interfere with the pattern of tribal life except when invited to do so.

In more senses than one, Duguid was tireless in his commitment to Aboriginal welfare. In the course of long journeys through the outback in the 1930s he had traversed the country between the Musgrave and Petermann Ranges at five separate points by camel; and though he was now in his sixties he brought just the same resilience and vigour to his

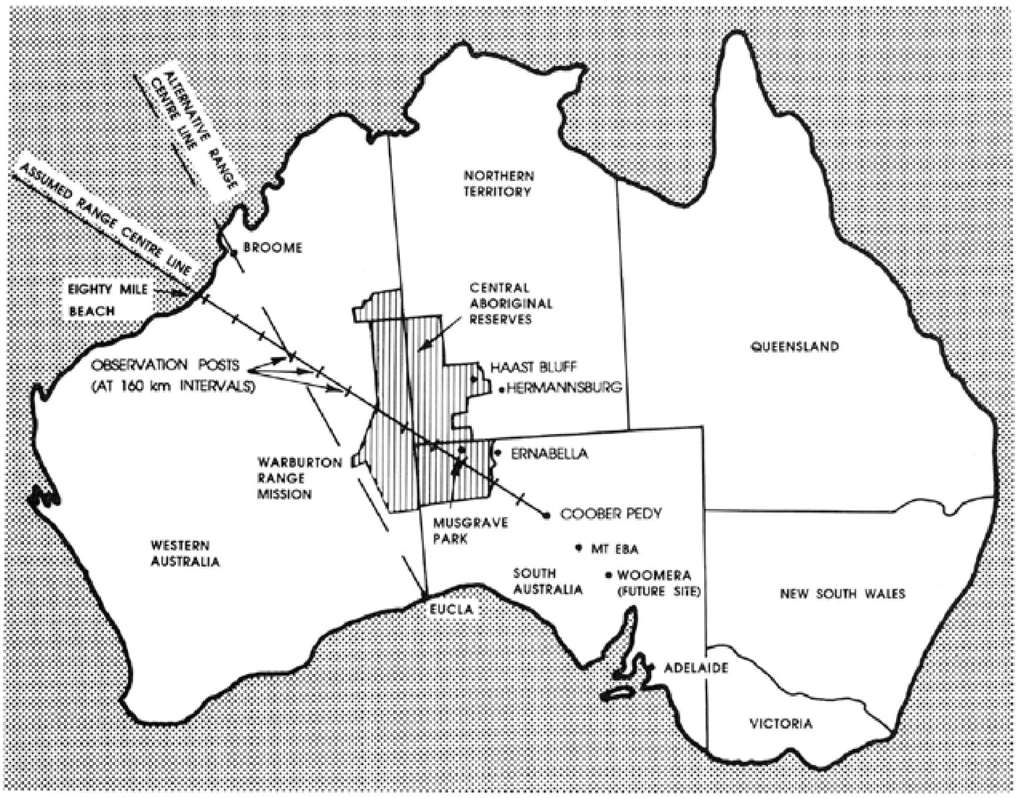


Ernabella Aboriginal Mission in the Musgrave Ranges.

role as chief polemicist for his cause. Duguid had a fluent pen and a gift for asking pointed rhetorical questions. 'What curse is on a civilisation', he asked, 'that, while the anguish of millions is still on our hearts, it should already be trying to devise a method of wiping out whole nations?' And another of his questions, though it betrayed a certain confusion about the proposed immediate purpose of the Range and was somewhat dramatic, did show remarkable prescience of future outcries: 'having driven [the Aborigines] from all the good country are we now to sit back and allow them to be treated as human guinea-pigs in atomic tests?' The development of 'atomic force', Duguid argued, is simply too important and too dangerous to be left to the military.

Because for the time being the whole project was so tightly under wraps, a jungle of rumour swiftly grew up in which the wildest speculation blossomed unhealthily. Flying atomic bombs, it was said, were going to be regularly launched and exploded, devastating large areas of the bush. Stations over thousands of square kilometres of the outback were to come under the thumb of the British military. One well-meaning correspondent suggested that all difficulties could be laid at rest by relocating the range in the Antarctic. Duguid himself raised a red herring by asking who would put out the bushfires started by test rockets carrying atomic warheads. The talk grew so feverish that moderates were moved to protest that the definitions being used so glibly were getting out of hand: one R. L. Parsons, a former army engineer, justly complained that the terms 'rockets', 'rocket bombs', 'atomic bombs' and 'atomic energy' were being run together as though there was no difference between them.

By July 1946 Duguid had been seeking details of the proposed route of the Range for more than three months, and in his extreme old age many years later he still recalled his amazement when a story from a London newspaper first came into his hands, with a map showing the Range azimuth line slicing right across the reserves.[6] Given his keen sense of responsibility it is easy enough to see how acute his worries must have been at that time. What the authorities wanted struck him and his supporters as monstrous: the right to shoot projectiles armed with explosive and possibly nuclear warheads many hundreds of kilometres across Central Australia. On the scanty information which had surfaced already, it was probable that the Ernabella Mission in the Musgraves and perhaps the outstations of Hermannsburg and Haast Bluff were directly threatened. No protest against such an outrage could be too strong.



The centre line of the rocket range slicing through the Central Aboriginal Reserves, as indicated by 1946 Press reports.

By early August the controversy had begun to take on a definite outline. It came even more into focus when AAP reported for the first time that establishing the Range would require the setting up of observation posts at 160 kilometres intervals all the way from 'a point near Coober Pedy' (presumably this location was given as being more familiar than Mt Eba) to the shore of the Indian Ocean. Duguid immediately picked up these new details. He was alarmed to find that if a straight line were drawn from Coober Pedy to Eighty Mile Beach on the north-west coast it ran straight across parts of South Australia, Western Australia and the Northern Territory and right through the fifteen million hectares of the Central Aboriginal Reserves with their population of about a thousand. On the figures given, three of the observation posts would be inside the reserves, and any rockets with a five to six hundred kilometre range would be crashing into them. The Aborigines, thought Duguid, needed a champion, and he was eager to take on the role. In his view, 'a secret military mission and a political dictatorship have forced us to become the arsenal of the Pacific'.[7] The fate of the poor Bikini Islanders, forced to migrate while their homeland was pulverised by American hydrogen bombs, had to be a warning. Only the most vigorous resistance could hope to rescue anything of the even more fragile Aboriginal culture. 'I refuse to . . . see them and their country offered in sacrifice to the moloch of militarism', he insisted in a letter published in the morning newspaper of 7 August 1946, and on the evening of that same day the first protest meeting, under the aegis of Common Cause, was held at the Institute on North Terrace, Adelaide. Common Cause had originated as a morale-raising campaign during the war, but by this time was devoting itself to various issues of social reform. It had no political ambitions, but the authorities found that hard to believe. According to a top secret Army intelligence report, Common Cause had been infiltrated by Communists and the Range protesters were either dupes or fellow travellers:

> Although not officially affiliated with the Australian Communist Party, 'Common Cause' is known to have many communist supporters in its midst. Its monthly newsletter is leftist in its viewpoint. 'Common Cause' rooms are used for meetings of the Australian Communist Party. It can be seen therefore that there are many close ties between the two organisations . . . Communist interest in the aborigine is evidenced in reports from Western Australia where a communist agitator D. W. McLEOD was recently gaoled for inciting the aborigines to strike. The true reason for communist interest in the aborigine can be seen in the following note from McLEOD to an unknown addressee that was produced during McLEOD's trial: 'Each and every one of these natives are potential Communists. In Pilbara alone we could recruit up to 1000 members for the party. It is our duty as Communists to relieve these people of their unhappy lot'.

But the only hard evidence that the writer could muster of the 'many communist supporters' in Common Cause was that three officials of the South Australian branch of the Communist Party—Dr Alan Finger, his wife Joan, and Alf Watt—were said to belong to it. The rest was just gossip, and in some particulars, for instance that Duguid had communist leanings, was absurdly false. There was no sympathy between Common Cause and the Communists. Indeed, a Party member was expelled for advocating a closer bond with what was defined as a liberal bourgeois organisation.[8] At the protest meeting Duguid himself was the principal speaker. If missiles were fired along the proposed route, he said, most of them would fall into the reserves. It would be impossible to contact everyone before the trials. Aborigines 'would inevitably be killed'[9] and the survivors' culture could not possibly long withstand the rumoured construction of a township within the reserves. The latter point now started to dominate in the controversy. In the last months of 1946 Duguid, perhaps appreciating that to concentrate unduly on the physical risks was to weaken his case, began to home in on the putative three semi-permanent observation posts inside the reserves and their supply by road. He rejected any comparison with the construction of the East-West railway which one could argue had already interfered with the privacy of the Aborigines; that, he said, had been 'inevitable' whereas the Range was 'a purely warlike venture'.[10]

Once it was couched in this form, Duguid was able to attract an impressive list of supporters for his cause, both locally and internationally: the South Australian branch of the Australian Government Workers' Association, the National Missionary Council, the Bishop of Newcastle, NSW, the Australian Women's Charter, the Intervarsity Fellowship of Evangelical Unions, the Women's Christian Temperance Union and a little later on, former Regius Professor of Greek at Oxford Sir Gilbert Murray, a good friend of Duguid's since 1937.

Murray, an Australian by birth, gave his opinion, in the form of a letter to the (London) *Times* that 'the stations will be worse engines of destruction than the bombs'.

But for neither the first nor last time in the troubled history of relations between white and black in Australia, various factions, each claiming to have the Aborigines' real welfare to heart, were already emerging. (Significantly, no one proposed finding out what Aborigines themselves thought, although at least three individual Aborigines protested against the Range plans at a very early date.) By December the Aborigines' Friends' Association, a group with an assimilationist philosophy, was claiming that natives who had been previously engaged in war work were looking forward eagerly to further employment by the military. Another point of view was that the Aborigines would benefit from the better national security brought by the Range no less than all other Australians. Stout dwellers in the outback pooh-poohed the risks, which they compared very favourably with crossing King William Street in Adelaide. A Mr Morley, manager of Mulgathing Station near Tarcoola, took his patriotic zeal so far as to declare that even if there were 'a thousand times greater risk' of having a missile fall on him he would be ready to take it to further the defensive goals of the British Empire. For example, he questioned, how much protection could the Aborigines look forward to from invading Japanese:

> I am certain that we of this country are 100 per cent behind the establishment of the Range [and] Australia should be proud to have the opportunity to be the testing ground for this great Empire of ours.[11]

Though this rash claim was scornfully rejected by some later correspondents, it received some weighty support. 'Hitler', said the Adelaide *Advertiser* sternly in an editorial, 'would have whistled a very different tune, perhaps, if there had existed in South Australia ten years ago a research establishment devoted to the work of perfecting British instruments of destruction'.[12] Premier Playford, whose government was fully committed to the Range, did his best to assure a restive Opposition that, 'adequate steps would be taken for the safety of Aborigines', but he could not be drawn any further than that. No, he had not seen any members of the Evetts mission after they had completed their inspection. Yes, he did have some information about the nature of the project, but it was all confidential. In any case, it was a Commonwealth matter, he told his tormentors; address yourselves to Canberra—'and much good may that do you!', was the clear if unspoken rider. Mr McIntosh, who was both Minister for Works and chairman of the Aborigines' Board, in turn insisted that it was 'evident' that the degree of accuracy of tests would be so great that even nomads would be at no risk whatsoever. Such governmental assurances, said the Aborigines' Friends' Association, in the form of its secretary the Rev. J. H. Sexton, were really all that was needed. For Duguid, however, such soothing noises were 'utter nonsense'.

THE GOVERNMENT ACTS TO ALLAY FEARS

In October Prime Minister Chifley had invited proposals for an alternative routing, and the Duguid party shifted ground a little to suggest that at least the firing point of the Range should be moved from Mt Eba to Eucla, near the point where the border between South Australia and Western Australia cuts across the treeless Nullarbor plain to meet the Great Australian Bight. From Eucla the firing line could be north-north-west towards Broome on the coast, passing to the west of the reserves. Although a federal Minister said this and other options were still under active consideration, the truth was that several alternatives to the chosen path had already been taken up and dismissed. This particular alternative had not come up before, but it had little merit. Its path overland would be some 300 kilometres shorter and it would have to cross the East-West transcontinental railway line. A rangehead at Eucla would have been hopelessly remote from industrial and population centres. Quite simply, it did not meet the British specifications for an ideal range. The effort of developing this alternative served to deflect and waste the energies of the protesters, which may have been the motive for the solicitation—Duguid, at least, thought so.[13] At any rate once the joint project had been formally agreed to in principle by exchange of Prime Ministers' cablegrams, the Australians felt able to issue the first authoritative public statement. This announcement was made in the House of Representatives in Canberra by the Minister for Defence, John Dedman, on 22 November 1946.[14] After referring to 'reports and criticisms of a speculative and to some degree uninformed nature' which had been circulating over the last months, Dedman outlined the broad nature of the project. He expected there to be little effect on the Aboriginal population: 'reports that huge areas in Central Australia will be blasted by explosives are highly coloured figments of the imagination'. Firings would not take place more than once a week on average, and in the case of expensive long range rockets very much less frequently than that. No explosive warheads would be used until control techniques had been perfected. If and when observation posts had to be established in the reserves everything possible would be done to safeguard the Aborigines from undue contact and to prevent encroachment on their sacred lands. For the immediate future instructions had been given that the Committee on Guided Projectiles, which had been meeting since 1946, should convene for special consultations with the Director of Native Affairs and other authorities concerned with Aboriginal welfare.

Most protests were silenced while the results of the promised consultations were awaited. But not all were content to wait. Mrs Doris Blackburn was Independent Labor Member for Bourke, and the widow of the lawyer Maurice Blackburn, MHR, whose espousal of minority and pacifist causes had once induced the ALP to eject him from the party. On 4 December 1946 Mrs Blackburn gave notice of a private member's motion

> that in the opinion of this House the proposal to establish a rocket bomb testing range in Central Australia is an act of injustice to a weaker people who have no voice in the ordering of their own lives; is a betrayal of our responsibility to guard the human rights of those who cannot defend themselves; and a violation of the various Charters that have sought to bring about world peace; and such action is against the interests of the whole of the people in this Commonwealth.


Professor A P. Elkin.

The Guided Projectiles Committee did convene on 31 January 1947 to examine the Aboriginal issue, and its first move was to co-opt the officers responsible for native affairs in South and Western Australia and the Northern Territory, together with A. P. Elkin, Professor of Anthropology at Sydney University. Elkin was an assimilationist who had little time for the notion of the reserves as sanctuaries. He took a pragmatic attitude to the Range. Having come to the conclusion that its construction was inevitable, he thought that those experienced in Aboriginal affairs should support the government and do whatever they could to help.

Evetts, who had arrived in Australia again earlier that month, also joined the Committee. When questioned by reporters about the danger to Aborigines along the route he merely 'smiled and said that . . . in the initial stages at least, warheads with explosive charges would not be used'.[15] If this suggests he had yet to become familiar with the arguments of the opposition or to grasp their moral authority, he very quickly rectified the omission. Barely a week before the next and crucial Committee meeting he wrote a personal letter to Chief Scientific Officer A. P. Rowe, recording his impressions of the latest Australian mood:

> My impression is that there is no opposition at all in Australia to the Guided Weapons Project on the grounds of war-mongering', but there is serious opposition being engineered, which is assuming larger proportions every day, on the grounds of interference with the aborigines, so that anything you can do to persuade Rivett and Oliphant to back us up in this direction will be of value. So serious is the pro-aborigine movement that I am flying to Canberra tomorrow to spend Friday with the UK High Commissioner to discuss this problem.[16]

Dedman and some of the more politically astute Committee members realised how vital it was to give Duguid a chance to put his views; and despite some objections he received an invitation, another being extended at very short notice to Dr Donald Thomson, an anthropologist who broadly shared Duguid's views although the two had never met. The Committee convened at the Victoria Barracks in Melbourne on 1 February 1947, and the co-opted members were first thoroughly briefed on the reasons for selecting the Range site and on the plans for its construction and use, so they could judge its likely impact. They were told that for the first few years only the first 500 kilometres of the Range would be developed, leaving it well short of the reserves. Even later on, few missiles if any would be allowed to fall in the reserves, and these would not be armed. It was expected that danger from fragments from an impacting projectile would be confined to a circle of 50 metre radius. On the vexed question of observation posts, the Committee was advised that it would be necessary in future to establish a few posts within the reserves, but perhaps no more than three. Once constructed, the posts would be manned only by small parties during firing periods, and possibly by a few caretaker staff at other times. (The suggestion was later made that these ought to be married men with their wives with them.[17]) There would be no arterial roads in the reserves, no employment of Aboriginal labour and no uprooting of people. The total population within the reserves was estimated at 1800, mainly in scattered nomadic groups. The sections of the Range outside the reserves were known to be even more thinly populated than that.

Duguid and Thomson refused to hear this secret briefing for fear of compromising themselves. When they were ushered in to present their case, Duguid's first impression was of a roomful of military uniforms and of a large map of Australia with the Range route scored across it.[18] In his testimony, Duguid adhered to his objection to the Range passing through the Central Reserves. He did not see the main harm as coming from the firing of rockets over the reserves, nor from dropping an occasional bomb within them. The main harm would be culture shock. He considered that whatever welcome steps were taken to protect the Aborigines, their lives would be interfered with by the inevitable contacts which must take place when observation posts were established within the Range. Thomson generally supported Duguid although, as he said himself, he was not sufficiently well acquainted with the issues to contribute much.

After careful deliberation the twelve man committee, including the six co-opted members, came to several important conclusions. They agreed that detribalisation of the Aborigines was in the long run inevitable; and, providing the contact between them and Europeans in the course of construction and use of the Range was controlled and 'wholesome' the only effect would be to put the process of detribalisation forward by perhaps a generation. On the basis of what they had heard proposed for the reserves, the Committee believed that the safety and welfare of the people living there could be assured. The only physical danger would be that resulting from some unforeseen event which, although it could not be guarded against absolutely, could be classified as a remote possibility only. Any other forms of interference with the Aborigines they felt could be discounted since there was no proposal to uproot communities, construct roads, or make any employment available.

The Committee felt that any interference with the habits of the Aborigines or with those areas of special significance to them which have existed from time immemorial, could be controlled by the appointment of patrol officers. One officer for the South Australian section of the reserves ought to be appointed at once, and others as the Range was extended. It had taken note of the views presented by Dr Duguid and Dr Thomson, but it concluded that 'neither of these gentlemen had advanced any reason which precluded the making of satisfactory arrangements to ensure the safety and welfare of the Aborigines in the proposed range area'.

Dedman, who must have read the Committee's report with considerable satisfaction, tabled it in the House of Representatives on 6 March 1947. He had prepared a statement to be made at the same time, as Mrs Blackburn's motion was to be debated then. The debate was however postponed, and so he released his statement to the press on 10 March.

First he dealt pragmatically with the pacifist objections to the project:

> It will be apparent from the advances made by science in the methods of warfare that the guided weapon is a reality which we must face, that should war unfortunately occur again, we could be subjected to attack by guided weapons possessing far greater range and destructive power than the VI or V2 used against England.

Already, Dedman pointed out soberly, 'other countries'—it could hardly be in doubt which one he meant—had in some respects transcended the German achievement:

> This means it is essential for the security not only of Australia, but of the British Empire as a whole, that our effort in research, design and development should be such as to keep us abreast of progress in this possible form of warfare . . . In the Governor General's speech, it was stated that Australia will make a larger contribution towards the defence of the British Commonwealth, and that this could best be done in the Pacific . . . The guided weapons project is the first practical measure to be undertaken. It will increase the capacity of Australia to defend itself with the latest weapons, which is important in view of our small manpower and large territory, and it will strengthen the security of the British Commonwealth by providing for the dispersal of these resources.

Dedman firmly rejected the charge that the Range in any sense violated Australia's peace pledges. Everyone, he said, would like to be able to guarantee peace and outlaw war permanently: such was the noble goal of the United Nations. However

> it is essential that we should not repeat the mistakes of the past, and unilaterally disarm. This would be a service neither to ourselves nor to collective security. In fact, Article 51 of the Charter provides that nothing in it shall impair the inherent right of individual or collective self-defence against the attack of an aggressor.

Finally Dedman took up the report of the Guided Projectiles Committee and its recommendations. After noting the dissenting opinions of Duguid and Thomson, he put the government's position thus: 'as the authorities on native affairs representing the Commonwealth, South Australian and Western Australian Governments and Professor Elkin are satisfied with the measures proposed to be taken for safeguarding the interests and welfare of Aborigines, the Government has accepted the conclusions of the report with which these authorities were associated'. He summed up in these terms:

> If we are not to be defenceless against an aggressor employing this type of warfare, we must keep abreast of its developments. Australia possesses the only area in the whole British Commonwealth most suited for the purpose. Successive Australian Governments have urged the decentralisation of the defence resources of the British Commonwealth and this is the first major step in this direction. I do not question the good faith of those who, in all sincerity, are concerned for the welfare of the Aborigines, but I do not concede that the Commonwealth and State Governments concerned are not equally solicitous for their responsibilities in this direction.

Dedman's carefully worded and comprehensive statement achieved its purpose: it quieted public fears and staunched the flow of protest letters. Effectively it marked the last stage in the controversy. On 1 May 1947 Mrs Blackburn's motion was put to the House and defeated on the voices; inevitably so, of course, because both the ruling Australian Labor Party and Menzies' Opposition heartily supported the joint project. The protest letters tailed off over the next few weeks, and almost the last act in the drama was the resignation of Duguid from South Australia's Aborigines' Protection Board, which he had been instrumental in founding eight years before. And there the matter petered out, flaring briefly only with Dedman's charge—at once angrily denied—that Duguid had told the Committee that he wanted no further information about the plans 'because whatever they were, he was opposed to them'.[19] Dedman declined the challenge, however, to produce a transcript of the testimony.

THE CONTROVERSY SUMMED UP

A. F. Martyn, Canberra physicist.

The issue of the Aborigines and the Range cannot be said to have tapped any deep vein of popular indignation. In those days few Australians cared much for Aboriginal culture: a physicist, D. F. Martyn of Canberra, probably voiced a common sentiment when he opined with heavy jocularity that natives were less at risk from advanced weapons than from the 'advanced form of psychological warfare practised locally with the aid of the directed bone'.[20] Nor, as we have seen, did the knowledgeable speak with one voice. Professor Elkin, in a backward glance at the issue after it had died, again discounted most of the fears and, in a pointed remark clearly addressed to Duguid and his party, enjoined them 'not to waste energy in futile protests or abstract arguments'.[21]

While it is absurd to dismiss the protesters as the dupes of international Communism, a more telling if exaggerated charge was that some of them were really pacifists whose smokescreen of rhetoric about Aboriginal welfare concealed a subversive view that the Empire should forego the right to defend itself. Whatever the exact shades of opinion existing among the protesters, they were in total only a tiny minority. Their opponents asserted that the joint project had the support of the 'silent majority' who recognised just how badly such facilities were needed in a hostile world. Very probably most Australians who gave the matter any thought did adhere to this view, though a Gallup Poll of May 1947 suggests that more than a quarter had no clear attitude to the Range at all. Distrust of Russia's imperialistic ambitions and fear of her technical prowess was already strong and, despite the shock of the fall of Singapore in 1943 and Australia's reliance on her American ally in the Pacific, emotional links with Britain remained powerful. Most people found it inconceivable that Australia's interests could ever differ markedly from those of Britain and her Empire; by and large they probably sided with the journalist who rejoiced that 'military science has found a use for more than 1200 miles of useless terrain'.[22]

In later years very little public concern was expressed about the Range and Aborigines, as the dangers so direly foreseen simply did not arise. No rockets went anywhere near the reserves for more than a decade. A small meteorological station at Giles, 900 kilometres from Woomera in the Western Australian reserve, was built in the mid-1950s and provoked a brief public row, but no other observation posts, not even temporary ones, were ever set up there. The assumption that such posts would be required at 160 kilometre intervals had been based on the proposed development of a 'flying bomb' (analogous to what much later became the cruise missile) travelling on a long low trajectory through the atmosphere. Once such plans had been abandoned, as they were at an early date, there was never any question of permanent posts within the reserves. In 1958, at the time of the Range extension to 1600 kilometres for the proposed Blue Streak trials, a few indignant comments were voiced that Aboriginal freedoms were being restricted by the patrol officers, whose job was 'to prevent nomadic tribes of aborigines on walkabout from entering the testing area',[23] but these complaints were muted and inconsequential. Not one guided weapon, armed or unarmed, was ever fired over very long distances from Woomera. The few distant firings to the north-west were part of two different satellite launching programs, and these did not come until the three flights of the first stage of the Europa 1 satellite launching vehicle in 1964-65. As a later chapter describes, one of these misbehaved in flight and was automatically cut down in accordance with the elaborate safety precautions always taken to minimise the danger from large missiles. Much of its debris did fall in the reserves, near the Giles station, but fortunately without incident. The other two Europa rockets passed high over the reserves as intended. In the whole history of the joint project, in fact, only one firing (again, during the ELDO trials) impacted even 1400 kilometres down-range. There is a certain irony in the fact that after all the outpouring of ink and emotion all the other very long range and potentially hazardous firings were not made in a northwesterly direction at all, but due north over more settled country.

Early in the life of the joint project, Native Patrol Officers were appointed to look after the welfare of all the Aborigines likely to be affected by it, and the first of these, Walter MacDougall, had the approbation even of Duguid who knew him well, felt he was ideally suited to the job, and regarded his appointment as the sole lasting benefit of the protest campaign. The work done by the Patrol Officers over a quarter of a century for the most part proceeded so quietly and without fuss that many project employees were hardly aware of it, but for all that it is a fascinating and colourful story.

Notes and Sources

1. An example of the kind of vigorous protest which went direct to the Prime Minister is this (condensed) letter of 18 June 1947, from G. Stead, Past President and cofounder of the Australian League of Nations Union:

   > I believe that Australia is embarking upon the most calamitous undertaking that has ever been entered upon in history. However it is camouflaged, the Rocket Project is at once the most dangerous and potentially disastrous thing; and, internationally, the most immoral scheme ever conceived by any people. Apart from the terrible danger to which it may expose every man, woman and child in Australia, it stands out among all international acts of all time as the most shameful proposal ever put forward—following, as it does, so soon after the Second World War (not yet concluded!), the foundation of UNO, and the solemn obligations entered into by us as a people to promote World Understanding and World Peace. This noxious thing is being done without the people's authority. With issues so grave and so full of the most dire threat to our life and liberty, it is clear, I think, that the electors should have been given all the true facts and implications of this scheme, and should have been allowed to give their decision on it before any such experiments were allowed to be carried on in any part of Australia. And this, even if under the aegis of UNO—the only acceptable authority to carry on any such investigations anywhere! We have heard much of the Guided Missiles which are to be experimented with on the Australian Rocket Range. What are these Guided Missiles for? They are for one purpose and one purpose only—indiscriminate wholesale killing of

> men, women and children! We can be killed in exactly the same way. Thus, Australia's own destruction is being prepared under our very eyes. It can be stopped, and should be stopped now! It must be stopped if we are to survive. It should be stopped, if only for the monstrous inhuman character of the Project; but Australia's honour and future security (that much-loved word), and even the continuance of the lives of our citizens, demand it . . . I hope that all Australians, men and women of the homes, scientists, trades unionists, workers in every profession and walk of life, will call upon the Government to abandon this wicked and dangerous project, and force Government to stop all operations, now before it is too late!

The Prime Minister replied briefly on 1 July, mentioning the same arguments as those employed in Parliament by his Minister in March and the previous November. AA MP1748 file GW/P/3 part 2. A copy of the Crawford playscript is on file.

2. 'Rocket bomb test site' (letter), *Advertiser*, 5 November 1946.
3. 'Rocket firing range', *Advertiser*, 20 July 1946.
4. 'Big area for rocket tests', *Advertiser*, 22 July 1946.
5. Rigby, 1972. Chapter 14 of this book, 'Rockets Over the Desert', is Duguid's summing up of his involvement in the controversy.
6. Interview by Paul Wilson on 22 July 1980. Wilson's thesis 'Rockets and Aborigines August 1945-August 1947: a study of the initial plans for the Woomera Rocket Range and of the protest movement which surfaced to challenge its implementation', Department of History, LaTrobe University, 1980 usefully brings together many threads of the controversy in much more detail than is appropriate here.
7. Charles Duguid, 'Guided missiles' (letter), *Advertiser*, 25 November 1946.
8. Memos dated 29 October and 1 November 1946 to the Secretary, Department of the Army. AA MP1217 Box 1656. For the communist view see Jim Moss, *Representatives of Discontent: a history of the Communist Party in South Australia* 1921-81, Melbourne, Communist and Labour Movement History Group, 1983.
9. 'Native lovers protest on rocket range', *Sydney Morning Herald*, 8 August 1946.
10. Charles Duguid, 'Natives in rocket area' (letter), *Advertiser*, 4 November 1946.
11. J. C. B. Morley, 'Few natives in rocket area' (letter), *Advertiser*, 2 November 1946.
12. 'Guided missiles' (editorial), *Advertiser*, 22 November 1946.
13. Wilson, p.24.
14. J. J. Dedman, 'The position regarding the setting up of a guided missile range and a supporting developmental establishment in Australia. Statement in the House of Representatives of 22 November 1946'. In *The Long Range Weapons Project*, Commonwealth of Australia, Melbourne, 1947.
15. 'Rocket team returns', *Advertiser*, 10 January 1947.
16. Letter dated 22 January 1947 from Chief Executive Officer J. F. Evetts to Chief Scientific Officer A. P. Rowe. File 5025.
17. Unless some special arrangements were planned for the observation posts in the reserves, this hardly squares with the requirements laid down by the same committee ten months earlier. The plan then was for the posts to be continuously manned to monitor up to fifty firings a year. A document, 'Provisional information for cost assessment for proposed GP range', of the same period was talking about posts with 'excellent living accommodation for twenty people', concrete underground structures, a storage shed and a garage for two jeeps and two heavy trucks.
18. Wilson, p.42.
19. 'Township to rise at rocket range', *Advertiser*, 17 May 1947.
20. 'Rocket research in Australia' (letter), *Sydney Morning Herald*, 4 November 1946.
21. 'Aborigines not doomed by rocket project', *Sydney Morning Herald*, 20 May 1947.
22. 'Flying rockets across half a continent', *Advertiser*, 25 March 1947.
23. *The Doctor and the Aborigines*, p. 152.

6 The work of the Native Patrol Officers

ABORIGINAL SETTLEMENT ALONG THE RANGE LINE IN 1947

For millennia before Europeans came to the place they christened Woomera, Aborigines had been wandering across the thousands of square kilometres of the Arcoona Plateau. They had done so despite its being a place of climatic extremes. While the mercury can fall below freezing on a winter night, day temperatures exceed 30°C—sometimes far exceed it—for about six months of the year. Any of the scanty precipitation which does not soak into the ground quickly vanishes under the fierce sun, which can evaporate off 2.5 metres of water in one year.

A few hardy species of vegetation dominate this geologically ancient Ordovician plateau. Small succulent bushes and scanty grass give way further out along the azimuth of the Range to bluebush, mulga and parakeelya, then saltbush and scattered myalls which eventually merge into the desolation of the Great Sandy, Gibson and Great Victoria Deserts. Yet a surprisingly wide range of flora and fauna do manage to survive, eking out a precarious existence between the better, wetter times which do come periodically if erratically. In such years all the life of the region undergoes a population explosion.

Although no tribal peoples were living on the Plateau when the joint project began, mute evidence was everywhere of settlement in the past. One of the most prolific sites was what is now the Woomera golf course, where scrapers and grinding stones can easily be picked up after a storm has blown away the surface sand. Examples also abound of artworks and ceremonial activities, rock carvings and standing stone sites. The wealth of artefacts, so dense in some places according to one anthropologist that it is impossible not to walk on them, suggests that in the past, perhaps the far distant past, the rainfall was more abundant and reliable than it is now.[1]

Aboriginal artworks at Eucolo Creek near Woomera, evidence of past tribal settlement.

Right: On 'walkabout' with traditional weapons—a partly assimilated group.

Far right: A 1950 down-range reconnaissance party fraternises with nomadic tribesmen.

Below: An Aboriginal stockman at Mount Clarence Station.

In those first days groups of partly assimilated, mostly English-speaking Aborigines were living within a radius of a couple of hundred kilometres of Woomera. A few were employed as station hands but most of them, about 250, made a living noodling at the Andamooka opal fields which lie 113 kilometres to the north-east. By the beginning of the 1960s, about a dozen young women were being employed as servants and nurserymaids at Woomera. Though the Department of Supply recognised that this inevitably led to liaisons which might not be in the girls' interests, it took the view that it had no right to deny them the experience of regular employment and wages. This was a typical example of the ethical dilemmas involving Aborigines which the joint project authorities had to do their best to solve, knowing that any decision was likely to be condemned from one quarter or another.[2]

Beyond the Plateau, far to the north-west, were still living in the early days hunter gatherers speaking no English, some of whom had never seen white people. Parts of their land had scarcely been traversed by explorers, and surprisingly little was known at the time of their numbers, movements and culture. We should recall that right up to the dying years of the project Australia's official policy towards its tribal Aborigines was one of eventual assimilation and economic self-sufficiency within white society. Until that time arrived (and it was admitted to be a long way off) Aborigines were to be kept physically segregated for their own cultural protection on the reserves and missions set up for that purpose. Only in the 1970s did the specific doctrine of assimilation give way to broader notions of self-management and self-sufficiency, with communities being encouraged to buy land detachable from the reserves.

The two reserves most often traversed by the Patrol Officers in the course of their duties were those adjoining each other on the borders of Western Australia and South Australia, through which the centre line of the Range ran. The total area of these, together with another abutting the border of the Northern Territory, is some 259 000 square kilometres. Often referred to collectively as the Central Aboriginal Reserves, they are geographically arid semi-desert: sandy plains and hills varied by low mountain ranges to a height of 900 metres. Vegetation is mostly spinifex with mulga scrub and grass around the ranges. There are very few permanent waterholes.

The Western Australian reserve, founded in 1918, was originally of 6000 square kilometres, to which another 4000 were added in 1958. The important Warburton Ranges mission was founded on a separate reserve of over 2600 square kilometres in 1934. In South Australia a total of 71 500 square kilometres of territory had been proclaimed reserve by 1949. Important settlements are Ernabella (founded 1937) and, 130 kilometres to the west, Musgrave Park cattle station and training centre (now Amata) which was established in 1961. The Aboriginal population of these reserves and the adjacent missions was probably about 1200 at the time Woomera was being built. For some time the numbers of both the tribal and detribalised groups had been increasing; the former because of good seasons throughout the 1940s and the latter because of access to more plentiful food and modern medicines which had more than offset the introduction of European diseases. They numbered rather more than two thousand when the Range's activities were at a peak in the mid-1960s.

Originally the reserves had been established as assured tribal hunting grounds, and in principle they were to be preserved inviolate for all time. In practice, however, they were constantly being entered by Europeans for one purpose or another: defence, mining, land and mapping surveys, even tourism. Western Australia issued entry permits much more liberally than did South Australia, but even the latter was granting permits in the late 1950s for very large oil drilling leases in the reserves. This is to say nothing of the illegal entrants, whose contacts with natives often went undetected since it would have taken a small army of officials to police them thoroughly. Mining companies sometimes took a cavalier attitude towards obtaining permits for their employees, and did not hesitate to make graded roads wherever they needed to.[3] It had become apparent, though, that the reserves were no longer serving their original purpose. The nomadic Aborigines had been drifting out of the desert for many years, and a decade or so into the project the reserves were practically depopulated with nearly all the tribesmen now living at the missions or the surrounding townships and cattle stations. In its last years the drift began to reverse again with the growth of the land rights movement, but by this time the project's activities were so diminished in scale that they were neither a hazard nor of interest to the new communities.

THE PATROL OFFICERS APPOINTED

W. B. MacDougall, first and longest serving Native Patrol Officer.

Most of this lay well into the future when, in accordance with the Guided Projectiles Committee's recommendation of March 1947 and the promise of the Minister for Defence, the first Native Patrol Officer (NPO) was appointed on 4 November 1947. But it was all to become familiar to W. B. (Mac) MacDougall. Educated at Scotch College, Melbourne, MacDougall had been an outback mission worker since 1931, first at Kummunya and later at Ernabella. He was to hold his new post until he retired twenty-four years later. Physically MacDougall was an imposing presence. Standing 1.9 metres tall, he was red-haired and craggy-faced with eyes of bright, transparent blue which would blaze when he was upset. One hand was badly disfigured; he had blown a thumb and forefinger off in an accident with a Winchester rifle. A man of stern and unflinching Presbyterian principles, he took his duties very seriously and was a natural loner. He was often heard to say that he began to feel constricted when he closed his first gate on the way back to civilisation.

Such was the man who, based at Woomera, was charged with the responsibility of looking after the welfare of all Aborigines whose life and culture might be affected by the activities of the Range. His patrol area was more than a million square kilometres, and on his constant journeyings through this vast domain he might cover 1600 kilometres a week, though in sandhill country he might make only 5 kilometres an hour, and use 4 litres of petrol doing it. His vehicle was at first a Dodge utility and later a specially equipped, one tonne, long wheelbase Land Rover with the fuel tank, sump, front differential and tie rods protected by steel plating. Extra tanks held 270 litres of petrol and 230 litres of water. He carried an elaborate kit of spare parts, and maintained transceiver contact with Woomera and several bases of the Flying Doctor Service.

Because the Establishment did not have any legal standing in the reserves except for matters involving security, it naturally had no official views of its own on Aboriginal welfare. Though an officer of the Commonwealth, MacDougall derived his authority to deal with the Aborigines of the WA and SA reserves solely from the native welfare departments of these two States. Thus the potential embarrassment always existed that the Commonwealth might be caught criticising state policies; and since MacDougall and his later colleague, R. A. [Bob] Macaulay, appointed 1956, did indeed object to some aspects of Western Australian policy in particular, their reports to the Range Superintendent were not infrequently censored before being passed on to the state departments.

These reports and memos still make fascinating reading. They offer a piquant contrast to the more mundane technical literature of the project. At times they were colourful and dramatic:

> Having waited several hours in camp I climbed a low hill to see if there was any sign of the people approaching the camp . . . An elderly man appeared and told me he had nothing that I would want and that he had only a woomera and one spear which he showed me and then placed on one side; then he advanced slowly lifting his feet high so that I could see that he was not dragging a spear held between his toes. I advanced to meet him and invited him to

enter my camp . . . some considerable time later a young man and a group of women and children entered the camp. They then told me how they had hidden and watched our every movement earlier in the day and how they had had to continue their day's hunt without the aid of spinifex fires through fear of betraying their exact position.[4]

We hear of such places as Kunmenutjara, the Place of Boils, and Utjurin the Green Caterpillar Increase Ceremony Grounds; and of such events as a girl sickening almost to death when she believed she had been 'boned'. Again and again, MacDougall stressed the strong subjective reality of these things. 'Waramala, the invisible avengers, upholders of tribal law and tradition, the protectors of tribal life, are very real to the tribal aborigines, [and] they are entitled to that belief until they believe something better.' MacDougall's attitudes do seem rather paternalistic today. Like many others at the time, he tended to believe that Aborigines, like children, are happiest when the rules of permissible behaviour are clear cut. But on any matter affecting the welfare of 'his' people his judgments were decisive and shrewd. Once when he was asked his opinion of a shepherding industry as an economic base at Ernabella mission, he made the point that one serious defect of the scheme was that it failed to offer 'the quick adventurous activity which appeals to all young men'.[5]

While everyone agreed that the Native Patrol Officers were able men, there were some murmurs as to whether some of their work should be supported by the joint project. After he had been on a tour to the north-west reserves of South Australia and elsewhere, the Hon. G. Pearson, SA Minister for Works and Aboriginal Welfare, wrote to WRE's Director, R. W. Boswell, saying 'your Department has far exceeded its obligations to native people which your activities would involve and has, in fact, developed a very sincere interest in native welfare generally'.[6] The remark was not intended critically, of course. But it was noticed that as time passed the Patrol Officers did indeed seem to be transforming themselves into welfare workers or even amateur anthropologists. Macaulay, in fact, believed his 'embracing function' to the Department of Supply was to 'supply a balanced, objective picture of Aboriginal life . . . not just as a people with curious customs, but as a vital living group'.[7] Thus in December 1958 he concerned himself with recording the cave paintings, mythologies and rituals of the peoples of the Mt Lindsay and Birksgate Range regions which were losing their population to Ernabella. As he said quite rightly, a permanent record should be taken of these practices before it was too late—and Woomera issued him a recorder and movie camera to undertake it, though a mild question was raised about its value to the Range.

While the defence money of two governments was flowing freely into project work, such criticisms were rarely voiced. The most the cynics could say was that the modest cost of the NPOs bought the Commonwealth a cheap insurance policy. Any public criticism that Aborigines had no champions at the Range could be soothed by the assurance that here were trained men in the field, paid from public funds solely to go about ministering to Aboriginal needs. But few saw anything wrong with that; in those days the state welfare departments were small and struggling agencies badly in need of some help.

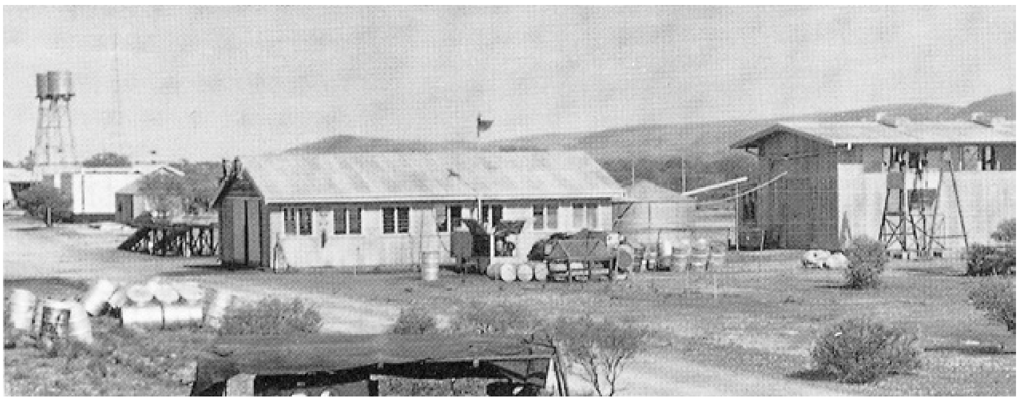
Though eyebrows might be raised at the relevance of some of the work the NPOs performed, their authority was never questioned while they were dealing directly with Aborigines, for they so obviously had their charges' interest at heart, and at an intimate personal level. For instance, in May 1959 Macaulay spent some time at Granite Downs station sorting out 'tangled relations' which had led to an outbreak of syphilis, saying that, 'apparently the Oodnadatta police make such blunt approaches to the Granite Downs natives that the latter become uncommunicative or "go bush" .'[8] They also occupied themselves with more orthodox health work. In December 1959 MacDougall made an elaborate tuberculosis survey, examining 400 Aborigines and arranging for 107 of them to be X-rayed at Leigh Creek hospital; and on another occasion Macaulay spent several days of a patrol in the Rawlinsons looking for a woman with suspected TB. Furthermore, their constant patrols added much to Australia's defective state of knowledge of its indigenous people. Even so experienced an observer as MacDougall himself was surprised to find, in 1952, about a hundred people in the northern part of the South Australian reserves who were still living almost wholly apart from white civilisation, visiting missions only once every two or three years. Though they knew dingo scalps could be bartered for flour, sugar and tea they apparently did not value these enough to trade systematically. Obviously this sort of information was barely relevant to Range activities but was useful to anthropologists and welfare agencies.

TROUBLE AT THE GILES METEOROLOGICAL STATION

It was when third persons, laymen like Range employees and Bureau of Meteorology officials, came into the picture that problems started for the NPOs. For example, the policy of minimum contact which the NPOs were pledged to uphold could easily be misunderstood. Its supporters argued that keeping the hunter gatherer way of life intact by physically isolating it was the only way of allowing tribal Aborigines to assimilate at their own pace and on their own terms, with a choice on which parts of their culture they wanted to Europeanise. From another angle, though, segregationalism, especially aspects of it like the ban in the reserves of sexual relations between the races, could look unpleasantly like Australian apartheid. And where was non-interference to stop? Were the reserves to be treated like African game parks where natural selection is allowed a free hand? Were WRE employees to be placed in the impossible position of watching Aborigines go hungry or suffer from trivial but painful disorders in the name of cultural autonomy? And if not that, then why were they instructed to let an Aboriginal family walk all day in the heat when they could easily be given a lift in an empty truck? Such questions were soon to gain a stark immediacy which they could never have in university departments of anthropology, for the reserves were about to suffer their first permanent intrusion in the name of Australian defence science.

Despite the early forebodings of Dr Duguid and his supporters, nearly a decade passed before any need arose for Establishment staff to encroach permanently on the reserves. Even when in 1955 the proposal was first mooted for a base within the borders of the Western Australian reserve it was not as a result of any joint project work. Rather, the request came from the Meteorological Branch of the Department of the Interior for the establishment of a weather station in connection with the forthcoming tests of the British atomic bomb at Maralinga. In order that the fallout plume should dissipate harmlessly and not drift over populated regions, it was vital to have information about upper atmospheric wind currents from a point far downwind of the test site. The weather station, named 'Giles' for the famous desert explorer, was established to supply this data. Giles was built, equipped and operated under a complicated formula. The United Kingdom government budgeted £75 000 sterling for the construction of the station; on the understanding that it would be run and maintained by Australia for at least ten years. The meteorologists supplied the professional staff and weather-watching equipment. The Department of Supply, via WRE, contributed maintenance men, vehicles, radio equipment, transport, food, fuel and postal services. In the end the British had to pay £82 438 to get the job finished; perhaps they were slightly consoled by the fact that after a few years the Australians had to find a startling £A44 350 for a new powerhouse.

Some suitable locations about 1200 road kilometres from Woomera were proposed by WRE staff at a planning meeting in Melbourne on 14 October 1955, but no one raised the point then that the proposed area was squarely at the junction of the Western Australian, South Australian and Northern Territory reserves. In mid- December a reconnaissance party examined and decided upon a 2 hectare site some 5 kilometres south of the eastern end of the Rawlinson Ranges in the Pass of the Abencerrages. The twin advantages of this site



The Giles meteorological station, 1000 kilometres down range, was established to give weather forecasts for the Woomera Range and for Maralinga.

were that it met the technical requirements and had sweet ground water readily available. Of less consequence, but still important, was that the spot is a very scenic one. The Western Australian Department of Native Welfare, on being approached, made no difficulty about excising a suitable portion of land from the reserve and leasing it to the Commonwealth for ninety-nine years. On the contrary, the Department made no secret of the fact that it was looking forward to much more scientific and industrial activity in the outback, and that it was prepared to abolish the reserve, if necessary, to promote it.[9]

The necessary access road to take truckloads of building materials into this remote area posed more of a problem. The natural inclination of the Establishment was to grade a road to the site diagonally across the South Australian reserve from Emu Field, where the first series of atomic bomb tests had been held in 1953. It was perfectly well aware, however, that Dedman had promised that 'no roads of an arterial nature' would be constructed in the reserves; and though it had never been spelt out exactly what 'arterial' meant, it was pretty clear that hundreds of kilometres of bulldozed bush highway would never pass scrutiny. An alternative was needed. It was found in a track which had been built by a nickel prospecting company, running from the Alice Springs railway line across the northern portion of the reserve to Mt Davies in its north-west corner. (The Aborigines Board had agreed to this track, apparently, because of the national importance of uranium and nickel.) It was not the ideal route, but WRE Controller H. J. Brown deemed it expedient to enlarge this track 'just sufficiently well' for heavy equipment to be transported along it. The reasoning here was that if Dedman's promise ever came back to haunt the Establishment, it could be argued that 'the onus of constructing the track was on the mining company rather than on the Commonwealth Government'. This cunning approach, the Controller thought, should make everyone happy that they had exactly complied 'with the spirit of the Ministerial Statement of 1946, particularly page 19, paragraph 15(e) (Roads)'. To be fair to Brown, his position was rather invidious. Firm governmental guidance was lacking and he had no option but to deal with Aboriginal matters on an *ad hoc* basis.[10]

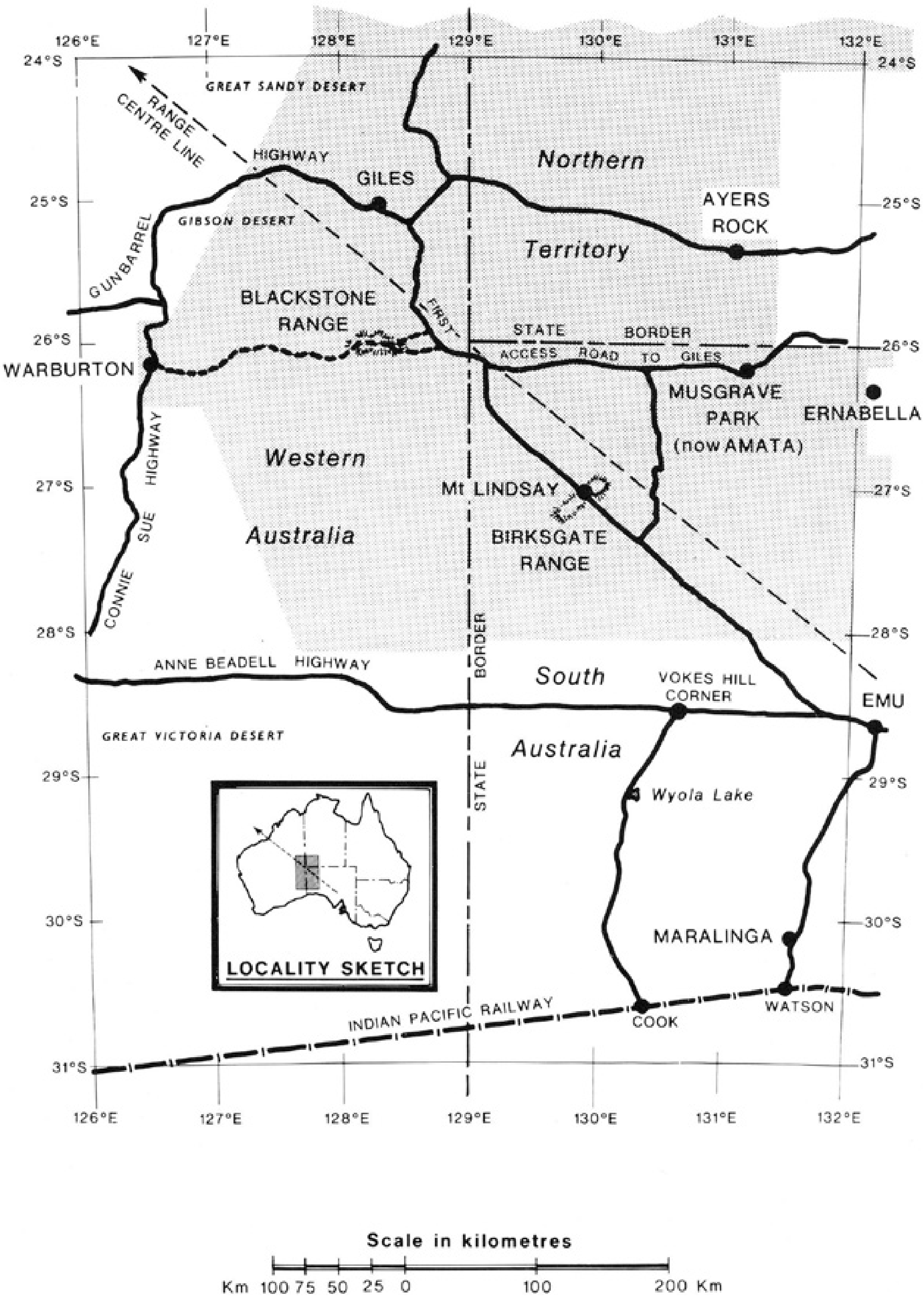
But this was to reckon without Walter MacDougall. His fierce objections to siting Giles in the reserve were already on record. He had taken part in the reconnaissance trip, and he believed, apparently with some justification[11], that he had been invited along merely to legitimise a decision already taken. 'There was no attempt made', he later reported indignantly to the Range Superintendent, 'to select a site that would interfere as little as possible with Aborigines occupying the Rawlinson Range'. On moving away from the rest of the party, he had eventually made contact with a tribal family group of nineteen people living close to the permanent water which attracted the Aborigines no less than the Europeans. He believed there was no reason why this pleasant place should not be left to be enjoyed by its original residents, since he understood that technically another site in the Warburton or adjacent ranges would do just as well. He summed up in no uncertain terms:

> The actions and attitude of the reconnaissance party shows that there is no intention of fulfilling or seriously regarding the promises made by the Commonwealth to the Peoples of Australia . . . progress and science must advance, but if existing measures necessary for the protection and welfare of Aborigines are obsolete, impracticable or to be disregarded, please publish the fact so that new measures can be taken, and organisations function smoothly and without false pretences.[12]

It was these 'false pretences', this hypocrisy, which most stuck in MacDougall's throat. The government had chosen a policy of minimal contact with the Aborigines; a policy which (he privately thought) was the wrong one since segregation, though very desirable in some ways, could not be kept up indefinitely. But there the policy was, and his job, as he saw it, was to make sure it worked; and it could only work if there was no traffic through the reserves, and contacts with tribal Aborigines were made only by qualified people. He did not expect that defence decisions made in the national interest would be dropped: what he did want was a public statement from the Minister that the rules had changed and promises rendered void.

In a further review of his position early in the New Year, MacDougall added he was aware that the 'disastrous alternative' was now gaining ground of allowing untrained whites to make the initial contact with nomadic Aborigines. 'The result,' he said, 'is certain to be a degeneration from self-respecting tribal communities to pathetic and useless parasites—it has happened so often before that surely we Australians must have learnt our lesson'. He also urged consideration of a critical moral issue which was in danger of being forgotten altogether: that for the first time in its short history the joint project was implicated in a claim on land which 'belongs to the tribe and is recognised as such by other tribes. However, we propose to take it away from them and give nothing in return—we might as well declare war on them and make a job of it.' He ended with the warning that 'if no remedial action is taken the matter could end as something of a first class scandal'.[13]

It goes without saying that these sentiments, expressed in these tones, did not endear MacDougall to his superiors. They were practical scientists and administrators with urgent work of national importance to do; men unaccustomed to wrestling with complicated ethical problems. Probably to them the last sentence quoted above had an ugly ring to it; it sounded, no doubt, more like a threat than a warning, particularly when MacDougall began to air his views in the press. MacDougall, far from being a voice of conscience, was to them an exasperating and intransigent officer who was meddling in affairs far beyond his sphere.



The Central Aboriginal Reserves (shaded), inside which Giles was built. At the time none of the roads on this map existed. The government had undertaken in 1948 not to establish any new arterial road in the reserves. Despite MacDougall's fierce objections, Len Beadell (who drew this map) was ordered to upgrade an existing track to give Giles its first access road. Beadell later built the 'Gunbarrel' and other highways shown.

A perplexed Controller Brown put the problem in a long memo to Chief Scientist Butement at the Melbourne headquarters, seeking his advice. The length of the memo and Brown's obvious care to delineate all the positions as carefully as possible suggests how seriously the matter was treated. He thought that 'in his present state of mind'—MacDougall was almost beside himself with rage at what he considered to be the betrayal of his Aboriginal charges—'he is likely to take some extreme step to draw public attention to what he regards as a breach of the promises made by the Minister for Defence'. So he had to be handled carefully. Were he to be dismissed, or pushed to the point where he resigned, he would certainly complain loudly and matters which were not for public inspection would be publicised. There were plenty of people, thought Brown, 'who would be only too ready to publicly raise objections to certain steps which are being taken' (a veiled reference either to Giles itself or to the Maralinga tests). It was important that those who had said the Government never intended to keep its promise on the continued isolation of the reserves should not be given powerful ammunition.

The moment was a delicate one in another way too, for soon another track would be needed, this time from Emu into the South Australian reserve for the passage of air monitoring equipment in connection with the Maralinga atomic trials. Though the Controller thought that this too could be made to conform to the 1947 promise

> as there is the question of radioactivity inherent in this work, it is obvious that any objections Mr McDougall [*sic*] has already raised concerning the northern access track will be raised again as soon as he becomes aware of this new proposal.[14]

This was indeed certain because MacDougall had already expressed disquiet about the effects of fallout in the reserves. That there would be some fallout had been conceded, but the official assurance was that it would not reach a level harmful to health. At the boundary to the reserve, about 112 kilometres north of the test site, it was said that the 'worst case' fallout would give a radiation dose considerably less that half the permissible limit established by the Americans for their Nevada trials. This, it was claimed, 'would be quite safe for a native in his "native" state, i.e. naked and without boots'.[15] Even though the trials were not strictly enterprises of the joint project but the subject of a separate agreement, many of the joint project facilities at Woomera were used. In particular, both NPOs were given the duty of making sure that Aborigines were not living in the test zone during or after the trials. Their reports, and the evidence presented to the Royal Commission into the nuclear tests in 1984-85, prove how impossible was this task.[16] For example, in the appendix to a report of 10 July 1959 both Patrol Officers expressed their apprehension that Aborigines were then, twenty-one months after the last test, living far inside the Prohibited Zone. From the air MacDougall saw hunting fires close to a road leading to the test site. On the ground a patrol met a group of thirty-four tribesmen at Wanna Lakes, who spoke of more people to the east, closer to Maralinga. The report warned that the 'safety factor' might come under public scrutiny and that the Commonwealth was open to the 'criticism that it takes inadequate safety precautions, lacks responsibility towards natives, and is careless and indifferent to their physical plight and health'. About a year later another patrol discovered an unrecorded tribal group of fourteen, including eight children, who had long lived in the Lake Wyola area some 120 kilometres from ground zero. They said that they had heard the atomic blasts and had been terrified. In short, the NPOs found ample evidence to substantiate Macaulay's summary that 'natives have been living *well inside* the Maralinga Prohibited Zone *continuously* from before the establishment of the Atomic Weapons Testing Grounds'.[17] Since the NPOs lacked both specialised knowledge and instruments, they could have done nothing to protect their charges from irradiation if it had been inflicted on them. MacDougall's fears and his anger, therefore, proved in the event to have been by no means inappropriate or misplaced.

In dealing with the immediate problem of the obdurate Patrol Officer, however, Butement recommended the firmest action. As he saw it, critical decisions had already been taken at the highest level of government:

> It behoves all of us to implement them with the least possible upset to any existing economy in the territory concerned, whether it be aboriginal or pastoral. To this end, and this end only, will Mr McDougall's [*sic*] services be utilised . . . He is out of step with current opinion, and the sooner he realises his loyalty is to the Department which employs him, and which is glad to take advice from him on matters on which he is an expert, the sooner his state of mind will be clarified, and he will be enabled to carry out his duties without any sense of frustration

Grading one of Beadell's 'gunbarrel' roads.

> or disappointment, as is evident in your assessment. There are doubtless many tasks upon which Mr McDougall's services can be more profitably engaged than in debating whether or not the policy enumerated by the Minister for Defence in 1946 is being correctly interpreted.

In short, he was guilty of 'apparently placing the affairs of a handful of natives above those of the British Commonwealth of Nations' and he ought to be forcefully informed that public servants do not make statements to the Press.[18]

Whether Brown conveyed the exact terms of this vituperative attack to MacDougall is unclear, but somehow the Patrol Officer was made to accept the position. The minimum access track was graded by the experienced surveyor Len Beadell and his 'Gunbarrel Road Construction Party' and the station built. Starting operations in August 1956, it consisted at first of thirty partly prefabricated buildings. Its personnel fluctuated over the years, but was typically twelve including the WRE contingent of five. The officer in charge was usually, but not always, a WRE appointee until 1972 when the station passed entirely to Bureau of Meteorology control.

Perhaps MacDougall had been placated by the news that a second Patrol Officer was to be appointed to work in the west. The new man, R. A. (Bob) Macaulay, was young (only twenty-three), and came with the recommendation of Professor Elkin of Sydney University, under whom he had just completed an honours degree in anthropology. At first he seemed green to the seasoned men of the Range.

R. A. Macaulay, the second Patrol Officer appointed.

In his first months the inexperienced Macaulay was rather sanguine about the effects of the station. He felt that both sides were accommodating themselves to the new situation and that interaction between the two races was healthy and stimulating all round. Here, surely, was the chance of a controlled experiment. Under the watchful eye of a Patrol Officer, tribal Aborigines could learn slowly and safely how most Australians lived, the weathermen being in this respect better models (he thought) than the missioners. He reported that first attempts at parasitism had been thwarted, and now 'without a doubt the Rawlinson natives have already woven the met. site and its attendant activities into their social and economic organisation and into their psychology'.[19]

Unfortunately such optimism proved far too premature. The trouble was that neither side could be persuaded to take the notion of mutual detachment seriously. To the Aborigines the station was the source of delightful and useful gifts; even its rubbish dump contained a treasure trove for a materially impoverished nomad. Some of the good natured met. men, and some of their superiors as well, thought that the doctrine of no fraternisation was being taken to fanatical extremes. What harm could there be in doing a good turn which cost nothing? They found it difficult, for example, to see any sense in Macaulay's edict that the ban on dispensing 'white man's food' also included the shooting of kangaroos as gifts. They also took a very dim view of being asked to chase people away from the water tanks, and in this they were supported by the Bureau of Meteorology which feared that anyone doing so would 'immediately leave himself open to being accused of assaulting natives, and this could not be accepted'.[20] But to their surprise they found Macaulay was prepared to insist that the rules existed to be obeyed. Concerned that the tribesmen might become parasites on the station, he ordered that all unused food should be incinerated and no cough syrup, aspirin or other medicine should be supplied 'except of

Young Aborigines joyriding on a reconnaissance Land Rover.

course, in deserving circumstances'.[21] When two Western Australian Members of Parliament, Pastor Doug Nichols, and a policeman turned up at Giles and could not produce their entry permits Macaulay, full of youthful zeal, promptly reported them all to the Department of Native Welfare. Len Beadell, already a veteran of the bush, was staggered when he found himself reported to Woomera for an action 'detrimental to the native way of life': namely, taking an Aboriginal guide with him in his Land Rover to help with a survey.[22] It should be emphasised that Macaulay was acting scrupulously within the Giles standing orders and in accord with the best anthropological thought of the day. He did intervene when conditions became critical in times of drought. In January 1962 the fifty or so Aborigines at the Giles camp were in a parlous state, with food so scarce that children were seen eating grass and leaves. The staff were shooting a few skinny kangaroos for them and 9 kilograms of flour were being issued every day. They were about to be invited to move to Warburton when the drought broke. Macaulay knew how to be flexible but dealing with the real nub of the Giles problem—bored men with few resources cooped up for months in a remote station built with few concessions to the climate—was beyond his control.

Barely a year after Giles was established the worst fears were realised: it became embroiled in a short but fiery controversy about its treatment of nearby Aborigines. As it happened, this was to be the only occasion in the history of the project that it came to public notice after the initial trouble over the building of the Range. Perhaps some attention was inevitable. Giles was a highly visible and vulnerable target of criticism because its situation put under a floodlight the contrast in way of life between the blacks of the region and the interloping whites, and showed up some of the strains in the minimal contact philosophy.

The unwelcome publicity took the form of a report by a Western Australian All-Party Select Committee; a report partly based on trips to the Giles area by the Committee's chairman William Grayden (MLA for South Perth), who later expanded it into a book, *Adam and Atoms*, published in 1957. Its author was a journalist by training and the book made very unpleasant reading for the authorities at Woomera and Salisbury. It reinforced in more inflamed style what MacDougall had been saying; possibly Grayden was briefed either by MacDougall himself or a missionary intermediary.[23] Grayden charged that MacDougall's predictions had been borne out: the construction of Giles near the oasis of Sladen Waters, a focal gathering point of Aborigines, had denied them access to the only good portion of the northern half of the reserve. Their game had been driven away by shooters from Giles who had also spread poison bait for dingoes which could harm native dogs or contaminate water supplies. He made much of the fact that nearly 250 kilometres of access roads had been built through the reserve, some of them wide and fast, and that more tracks had been built radiating out 20 kilometres from the station to connect with bores. These could only serve to bring the local entirely tribal Aborigines into contact with whites, with the consequent disintegration of their culture. Already, he said, fatal infections had been caught from the men at Giles. There had also been interference with the native women, and here Grayden added some lurid details:

> It must be remembered that a large number of road and other workers were employed on the Giles project. Many of these were New Australians. Among the employees were many who go to isolated areas simply because they have reason to do so. They had no respect for the native or for their way of life and . . . took every opportunity to fraternise with the natives. When W. Grayden visited the Giles area in August last year, some of the employees recounted how a native woman had given birth to a baby less than 200 yards from the Meteorological campsite, and how most of the employees had gone down to witness the birth and photograph it.[24]

He further claimed that some Aborigines camped at Sladen Waters believed that one of their men had been shot by a Giles employee and that the group had fled in terror to Warburton mission. Despite the fact that the patrol officers had for months been submitting reports detailing the extent of Commonwealth interference, nothing whatever had been done.

Grayden's most damning indictment was undoubtedly his description of a native camp he had seen some 8 kilometres south of Giles, compared to his memories of a similar group, containing some of the same people, on an earlier occasion before the station was founded:

> The change in the natives is most marked. They were then a clean, proud people. They camped near Sladen Waters within easy reach of a rock hole, situated towards the top of a gorge in the 800 foot high Rawlinson Ranges. In their camp at the Pass of the Abencerrages with the sheer ranges rising behind them, they were a people virtually untouched by civilisation. Apart from easing their lot by ensuring permanent water which would attract game and by providing a measure of medical treatment, it seemed sacrilege that their way of life should ever be interfered with—in some ways it seemed to be so superior to our own. Now, however, we find them camped ten miles from Sladen Waters, on the bank of a dry watercourse. Each day the Commonwealth officer takes water to them. They sit covered in flies and clothed in white men's rags, in the red dust. Their hair is matted; their noses are discharging; they are diseased with trachoma and yaws. At the Weather Station only five miles away, the employees have every comfort. Their mess hut and lounge is fly proof and air conditioned, iced water is available in unlimited quantities. Bottles of various cordials line the shelf above the water siphon. Similarly the living quarters and ablution facilities for the employees are as luxurious as money can make them. It seems inconceivable to us that white men can thus intrude upon the land of these aborigines and violate their way of life on such a scale and yet give nothing-—;not even medical attention—in return. An hour earlier, the same Commonwealth officer who now walks with us stood in the air-conditioned Weather Station mess and glibly expressed the view that he could 'maintain the status quo for a few years yet!' We wonder what his reactions would be had he known the natives who are in his charge and with whose condition he is so satisfied, a few years previously.[25]

For a while charge and countercharge flew freely, becoming so tangled over such issues as the exact site and size of a waterhole that the historian must retire defeated. No fewer than three separate investigations looked carefully into the complaints: a WA state government party with an expert medical team attached; an anthropological survey led by Dr R. M. Berndt of the University of Western Australia; and a press air expedition led by the newspaper proprietor, Rupert Murdoch. Between them the three surveys did much to calm public disquiet, though they did not give a very attractive picture of the scavenging habits of the Aborigines around Giles. In the end it was generally conceded that the health of the Aborigines was reasonably good, and serious conditions were treated properly. They were not starving; it was said that Grayden had lined up the thinnest natives he could find and had photographed them scrambling for tinned food to prove how hungry they were. The flight in terror from the supposed murderer was a much embellished version of a minor incident. The story of the photographing of the woman in labour seemed to be a conflation of two incidents: one where a birth was witnessed by the Giles handyman, and another where a small group had gone to visit a mother and baby some days after the birth and perhaps had taken snapshots. However, on neither occasion had an NPO been at the station, so it is impossible to be sure exactly what happened.[26]

Though the Giles station lapsed back into relative obscurity after the Grayden report had been found wanting, this is certainly not to say that no problems existed. In fact they were plentiful, and a constant headache to the Patrol Officers. It quickly became evident that Macaulay in particular, who had been appointed to work out of Giles, was being given a baptism of fire. For the truth which Grayden had missed was that in these years Giles was an unhappy place. There was a constant staff turnover. The men did what they could with their rather too ample spare time: planted a lawn and tended a vegetable garden, built an aviary and barbecue, and kept the grounds very clean and tidy. But the atrocious climate and the monotony were hard to bear, and the latter was accentuated by the strict ban on all except the very few authorised visitors. After being reprimanded for entertaining illicit guests, one observer-in-charge was moved to a cry from the heart: 'six months of seeing only the same seven other faces day after day' had made the personnel almost desperate for visitors, 'just to hear someone say something that we haven't heard him say one hundred times before.'[27] That was in 1970, and soon many more tourists began to pass through. Before then, the lack of facilities (none at all existed for women) and the fact that very few people could get permits to travel by road through the reserves made Giles as isolated as a lighthouse and as chaste as a monastery. The monsoonal rains which periodically turned the dirt runway into a quagmire, making it impossible for the monthly supply Bristol to land, further emphasised this isolation. Apart from the badminton court the only outdoor recreations were photography and shooting kangaroos to make skin rugs. Macaulay's attempts to ban these pursuits on the grounds that neither served the Aborigines well naturally caused more friction. Even private jaunts out beyond a small radius of the station were forbidden.

Certainly the job of Macaulay and MacDougall (for later they alternated tours of duty in the Giles neighbourhood) was an unenviable one. Giles served as their patrol base, and quarters were maintained for them there. Thus at times they lived cheek by jowl and on familiar terms with men whose behaviour they were required to police. They risked being thought of as paid informers; officials hired to 'dob in' their mates for breaches of rules which struck almost everyone as pointless. Not surprisingly, when the opportunity to do so arose the NPOs recommended moving their patrol post to the abandoned South Western Mining Company's camp at Blackstones. But for some reason this proposal was not acted upon, though Macaulay took to camping near the station rather than staying in his quarters there.

Then there was the problem that the NPOs were the servants of three masters: the Department of Supply via Woomera, and the South Australian and Western Australian departments of Aboriginal welfare. By January 1959 both officers were unanimous that their job was being made ten times more difficult because of, as they put it, 'constant white-anting' of their minimal contact policies by the Western Australian Native Welfare Department. Even though they reported that 'teenage girls are photographed with cigarettes dangling from their mouths land) station personnel continue to visit the camps and to trade whenever the NPO turns his back',[28] that Department did not appear overly concerned about the handouts of presents and services, and it continued to dispense permits freely to tourists. As well as this, for more than two years the NPOs had to contend with a tiresome muddle about the exact chain of command. Somehow the confusion had arisen that their immediate superior was the officer in charge at Giles; and since the first two of these had had little enthusiasm for keeping Aborigines away, they allowed their staff to ignore the NPOs' instructions or else actually countermanded them. Not until September 1958 was it formally recognised that in the relevant matters 'the Officer in Command, Giles, should be guided by the advice of the Native Patrol Officer', and even this failed to put an end to the constant friction. Morale reached its absolute nadir at the end of December 1959. On Friday the eighteenth the officer in charge of the met. personnel, H. D. (Dud) Collins, told one of his colleagues he was feeling depressed and was going for a drive in the bush. Uncharacteristically, he took a rifle with him. He did not return and after some time the alarm was raised. A search party eventually found him dead inside his Land Rover with a rubber hose from the exhaust wedged into the window with a handkerchief. He had some domestic and health troubles, but the Coroner was also told that Collins had been so worried about the scope of his authority that he had been ill and unable to sleep in the weeks before his suicide.[29]

From the early 1960s on, things slowly began to reach a more even keel. Some basic improvements were introduced, such as better air-conditioning, an extension to the mess, and later a pool designed and built by the men themselves. The tours of duty were made much shorter than the twelve or even sixteen months which had formerly been the rule, and this removed some of the stress of isolation. By the close of 1964 staff relations had so improved that the met. and WRE men were jovially swapping presents under a Christmas tree. More recently still, women have served tours of duty and with the loosening of restrictions on tourists the cooler months now see hundreds of fresh faces passing through the campsite. For a time the Aborigines began to leave the station environs. By mid-1963 fewer than fifty were camped in four or five family groups within a 200 kilometres radius of Giles. But there were still constant problems with theft, including a case where a store door was smashed and some bird seed stolen.

Such events were of course symptomatic of the disruption to the tribal patterns of life which the introduction of an outpost of European civilisation could not help but induce. Some of the harm resulted simply from the opening up of the country, and here Giles played its part along with the mining leases and the Warburton mission. All of these markedly accelerated the pace of detribalisation, and the three together, as Macaulay said drily, 'have proved just how inviolable was the Reserve'.[30] Even if its presence could be justified on defence grounds it was still an intrusion, and in the years after it was built hundreds of whites passed along its access roads, few of whom could have penetrated the reserves otherwise. Then from the very first the station itself was a magnetic attraction, and the Aboriginal camp was usually no more than 2 kilometres away. In the early days women and children spent a good part of their time picking through the dump looking for oddments of food, and even after the kitchen waste was incinerated they scavenged for anything useful, posting lookouts round the camp to spot where rubbish was going to be tipped. Thus their material culture was quickly affected in some minor respects: wooden bowls for carrying water, seeds, berries, fruit and so on gave place to empty caustic soda cans whose contents had been used to generate hydrogen for the weather balloons. On one occasion these changes in cultural habit had a fatal consequence. In May 1960, Tyadin, a child of eighteen months, was found suffering from advanced malnutrition in the Giles camp; and although the Flying Doctor Service took the child straight to the Alice Springs hospital it died soon after. However, this was undoubtedly an exceptional case: the other children were enjoying their usual good health and the camp folk did not take the matter lightly. Macaulay reported that 'all the other Rawlinson natives blame Nowina and Malguia lthe mother and father) for hanging around the rubbish dumps at Giles and for not providing bush food for Tyadin. Nowina was extremely fortunate to escape spearing in the thighs.'[31]

In a sense the child was a victim of what Macaulay called the 'parasitism of the mind': progressive cultural decay caused by coming into contact with a materially richer society whose people could be seen defying the tribal laws with impunity. The devastating effects of such contact have been observed elsewhere in the world. It fell to the Patrol Officers to try to buttress the 'old ways' even as they were being undermined. But this was a holding operation which, for better or worse, was ceasing to be necessary. The reserves were emptying through the most active years of the project; as early as 1960 the tribal population of these vast areas was down to a hundred or so in the Rawlinson and Blackstone Ranges. Segregation was quickly ceasing to matter; practically nobody was left to benefit from being kept apart. It was time for more constructive thinking. MacDougall saw, realistically, that the retention of the reserves, especially of the broad tracts of good grazing country, was 'becoming increasingly hard to justify'.[32] Both NPOs agreed that the most critical need was for some economically self-sustaining projects. They thought the reserves, or parts of them, ought to become training grounds for an Aboriginal-controlled grazing industry, though they saw very clearly that their charges faced 'a long, difficult and extremely speculative future in their way towards assimilation'.[33]

But certainly the immediate benefits of Giles should not be disparaged. The advent of the station meant that about 100 Aborigines were able to continue living in their native country in a time of drought. It meant the coming of some sort of barter economy. At this time informed observers judged the bush diet to be adequate and surprisingly well balanced nutritionally. It consisted of meat (kangaroo, rabbit, euro, dingo, emu, goanna, lizard, grubs and birds); vegetables (seeds, nuts, berries); fruit (quandong) and honey from ants and mulga trees. It was a monotonous diet, though, and now they could trade dingo scalps, which carried a bounty, for food 'luxuries' without their primary dependence on the land being upset. They could form a better impression of mainstream Australian life than from the atypical mission existence. They would no longer die of simple complaints like appendicitis which can be fatal without medical intervention. They were offered some protection against exploitative white intruders.

Even before Macaulay resigned on 10 August 1965 after nine years' service (his replacement was Robert Verburgt from 1965 to 1969), the Department of Supply had made tentative moves to dispense with the Giles station. Its original purpose, making meteorological observations for atomic tests, had long lapsed and would never be revived. After the cancellation of Blue Streak it was asked whether the joint project could not do without Giles altogether. The matter came up again more pointedly in 1965, but as on the first occasion WRE put up a spirited defence of continued support on the grounds that it needed long range meteorological information in connection with Skylark, Black Knight and perhaps in the future Black Arrow trials. (Woomera's high cloud cover tends to come in from the Indian Ocean, especially in winter.) In 1967 the Department of Supply put forward a formal memorandum advocating withdrawal from Giles, but this was again resisted by the Deputy Director of Trials because of the needs of the ELDO program. By July 1970, with ELDO ended, the Establishment finally agreed that the expense of Giles, some $60 000 a year, had become intolerable. It was prepared to pay the penalty of pulling out, either in the shape of poorer forecasting if Giles closed down, or by paying rather more for those forecasts if the Bureau of Meteorology went on alone. Naturally the Bureau was not keen to see WRE's support disappear, but it bowed to the inevitable and took over sole charge on 1 July 1972. It naturally followed that since the need for a patrol officer in the west had now come to an end, the office itself should come under critical review.

THE NPOS UNDER REVIEW, 1968–74

As we have seen, the Commonwealth, and more directly the Superintendent at Woomera, had for many years interpreted the responsibilities of the Patrol Officers most liberally. Right through the 1950s and 1960s very few limits indeed were imposed on these officers' own conception of their duty, especially in the matter of how many patrols were undertaken each year. But in July 1968 came the first intimation that they might become victims of the new financial stringency. The Central Reserves Committee, which had the NPOs among its members, was intent on holding its fourteenth session at Giles. The cheerful justification that the remote Giles was 'admirably placed for such a meeting' and the fact that thirteen people including three from WRE would need to be transported and lodged there would no doubt have passed without comment in more palmy days; but now the application gained some tart marginal comments ('Thirteen people to Giles!?') from the Deputy Director, Engineering Wing. The venue was quickly changed to Woomera, but the warning signs had been posted.

The Senior Reconnaissance Officer, A. H. Segnit, was now asked to submit some notes on the work of the NPOs, and when he did so they were received very bleakly by M. S. Kirkpatrick, Deputy Director of Trials, whose painful task it was to implement the cost cutting measures. Kirkpatrick, and others also, found it incredible that many of the Patrol Officers' listed duties—even when 'interpreted fairly generously'—should reasonably be charged to the joint project. One item after another—collation of historical data; liaison with surveys and prospecting expeditions; issuing and checking entry permits—was annotated 'should be restricted to matters arising from JP activity', or even a blank 'not JP business'. After thoroughly discussing the subject with all the relevant Commonwealth and state authorities dealing with Aboriginal welfare, a departmental proposal was developed which Kirkpatrick made known to the Director in a report dated 2 August 1968. Range activities were being steadily wound down and after the ELDO trials were completed in June 1969 no further trials affecting the reserves were even a distant prospect. 'A number of practices which have developed over the years are no longer applicable', he reported, concluding that a thorough review was long overdue. He proposed that over the following half year the Superintendent at Woomera should 'look at the scope of the activities of our Native Patrol Officers to determine whether we are engaging in patrol activities significantly beyond our obligations'.[34] Despite this review a new NPO, W. M. Jenvey, was appointed after some delay to replace Verburgt. However, this was the last appointment. It was decided that MacDougall would not be replaced when he retired in 1972: he was now being restricted to two patrols a year, and some rather abrasive questions were asked in 1971 whether a proposed patrol was needed. What, indeed, was the 'need for *any* of the patrols being undertaken at present (e.g. to "locate and learn about sacred sites") strictly in the context of WRE's presence in the area?'[35] By comparison with the freedoms allowed in the past, such questioning sounded almost heretical.

When it discovered that the Establishment wished to phase out the Patrol Officers altogether, the Western Australian Commission for Native Welfare was dismayed. It believed that the Commonwealth had a permanent responsibility for the changes which it had wrought, especially the road system which had done more than anything else to break up the last remnants of tribal life. Commissioner Gare, who took a full part in the discussions, argued strongly that WRE ought to continue making a couple of patrols each year to maintain contact with whatever groups were left. Naturally WRE was not keen to be saddled indefinitely with this responsibility. It took the view that as more and more people, black and white, had access to the reserves, the influence for good or ill of the Range was diminishing to vanishing point. Woomera had ceased to have any presence in the reserves, and it could not see that it had any reason, moral or otherwise, to be further involved in Aboriginal welfare. The post of Patrol Officer ceased to exist in 1974.

It is incontestable that, even if the Range had never been built and Patrol Officers never appointed, the broad flow of Aboriginal history over the middle decades of this century would have been much the same. The gradual abandonment in Central Australia of the hunter gatherer way of life had little to do with the Range, and in its absence the drift would have continued, though perhaps at a slower pace. The medical care that the Patrol Officers brought with them meant a number of Aborigines lived who otherwise would have certainly died; and there is ample evidence that their other good works were manifold in a period when most Australians were either uncaring about their country's indigenes or else harboured frankly racist sentiments towards them.

The exact effect of project activities on the Aboriginal population is hard to define precisely, but except for the matter of Giles and the network of access roads it was surely negligible. Neither the building of Woomera, nor the work at the rangehead, nor even the down-range trials, had any decisive impact on Aboriginal life, whether nomadic or mission based. Even Giles was a relatively mild offender, as its more reasonable detractors conceded. Staffed as it was by Commonwealth officers and run under tight governmental supervision, the station had little chance of hushing up any serious trouble. To lay too much stress on the minor lapses of behaviour there is pointless, especially when we bear in mind the situation in this period at the prospecting camps. These were unsupervised except for occasional visits from officialdom, and their contacts with Aborigines were practically unregulated. The Patrol Officers' reports contain a constant litany of offensive and even criminal behaviour there: at one nickel-mining lease operating in the 1950s, three contractors in a row were sacked for continual drunkenness and the attempted rape of Aboriginal women, which moved one of its employees to remark caustically that his company apparently 'scoured the gutters of Adelaide for personnel'.

No doubt the project added its quantum to the process of finally obliterating the tribal way of life which had existed since time immemorial, but that quantum was small. MacDougall himself wrote some eloquent words on the subject in the very month that Giles started operations. The tribesmen of the area, he said, are

> hunters and gatherers with social customs, and codes of laws with harsh penalties, which cannot exist in contact with our civilisation. Their beliefs can be destroyed soon after contact with whites solely by their observing the white man contravening their laws and customs and not coming to any harm as a result—i.e., the white does not have to take deliberate steps to detribalise them. When their beliefs are gone they are left with nothing to hold on to, and it only needs the mistaken and misplaced kindness of the white to turn them into the pathetic and spiritless beggars, devoid of self-respect, which has largely been the history of contacts since the white man first came to Australia.[36]

Whether tribesmen ought to be given lifts on trucks is an issue which has passed into history, but liberals' 'mistaken and misplaced kindness' is still a destructive agent to be reckoned with. Aborigines of the Warakurna community, numbering about 150, still live close to the Giles station. Relations with the staff there have been harmonious for a long time now; newcomers are vetted much more thoroughly than in the past, and in the rare event of trouble an employee can be removed at very short notice. Liaison with the Aboriginal

Community Council is regarded as extremely important. The Council is always informed about movements in the reserve, and awareness of the importance of sacred sites has now reached a pitch where not so much as a post hole is dug until permission has been properly sought and given. Much tension has been reduced by a gradual balancing in the conditions of life of the two communities. Materially the Warakurna people have gained a great deal: they have an itinerant schoolteacher, permanent buildings, a store, and their own transport. The days of scavenging on the station's dump are long gone. But apart from the tourist trade in artefacts, theirs is still a welfare economy, for jobs are scarce indeed. Dealing with these taxing problems is still a major concern, but it is one which has passed to other hands, most hopefully to those of Aboriginal representatives themselves. We must conclude that, while some of the promises the Commonwealth made to the Aborigines about Woomera were not fulfilled, by and large it properly discharged the responsibility it acquired with its participation in the joint project. In fulfilling these obligations the competence and energy of its servants, the Native Patrol Officers, played no small part.

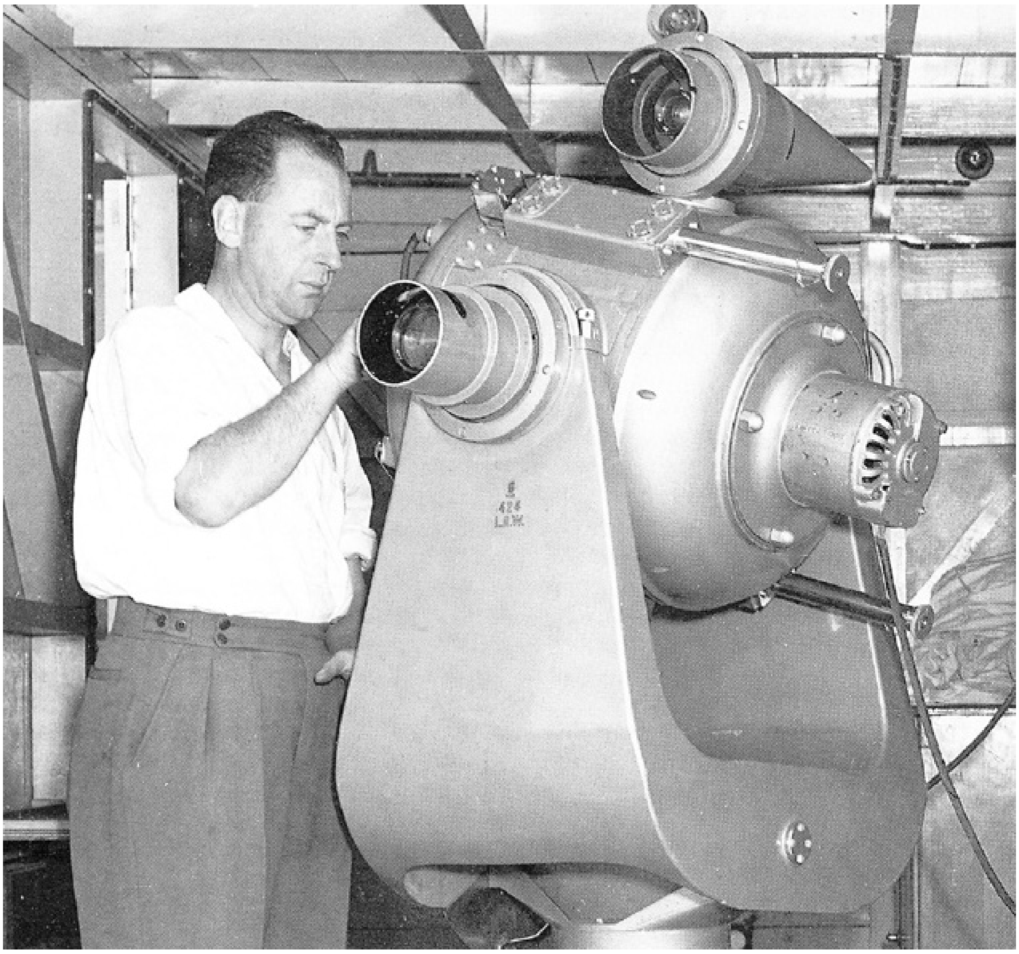
Notes and Sources

(Unless indicated otherwise, all the NPOs' communications were addressed in the first instance to the Range Superintendent at Woomera.)

1. Ron Hewitt, 'The Arcoona Plateau—an outline of Aboriginal habitats and relics', journal of the Anthropological Society of South Australia, 16 (August 1978), from which some of these details have been drawn.
2. Departmental policy on this question is mentioned in R. A. Macaulay, 'Some descriptions of certain aspects of Aboriginal life in Central Australia', an unpublished lecture of November 1961. Another problem about Aboriginal employment was posed at the time of the Range extension to Talgarno in 1959. The Commonwealth risked being caught in a cleft stick whatever it decided to do. If it gave employment the local pastoralists would be antagonised because they depended on cheap native labour and did not want to compete with the Commonwealth for it. But if the Establishment did not employ, it was open to the charge that it was not employing those eager to work when it could do so. 'Either way, in my opinion', said Macaulay reviewing the issue in a report dated 15 September 1959, 'this Department will suffer from publicity and ill-feelings revolving around the employment or non-employment of native labour.' Lecture and report in file 5288/1/1.
3. There is a specific complaint about this practice in an NPO report dated 17 December 1956 of a reconnaissance to the Rawlinson Ranges. File 5288 part 1.
4. NPO report of 17 December 1956. File 5288 part 1.
5. Letter of 16 August 1957 to the General Secretary, Board of Missions. File 5288/1/1.
6. Letter of 14 July 1960 from SA Minister for Works to Director R. W. Boswell. File 5288/1/1.
7. R. A. Macaulay, 'Some descriptions of certain aspects of Aboriginal life in Central Australia', op. cit.
8. Letter dated 22 May 1959 from Macaulay to the Secretary, SA Aborigine Protection Board. File 5288/1/1.
9. The Western Australian attitude is clear from a telegram of 8 November 1955 to the Department of Supply, Melbourne, and in a letter dated 15 July 1958 from S. G. Middleton, Commissioner of Native Welfare. File 5399/12/1.
10. Memo dated 7 March 1956 from Controller WRE to Chief Scientist W. A. S. Butement. File 5288 part 1. Commenting on these incidents Brown says, 'No firm long term policy could ever be obtained and so no one really knew how to act . . . Ministers' views were never definite except to say that the joint project must not be upset.' Letter of 15 July 1983.
11. For example, MacDougall is not recorded as present in the minutes of the planning meeting on 14 October. File 5399/1/2 part 1. This was confirmed by Len Beadell at an interview of 23 May 1983. An odd coincidence is that MacDougall's wife was the great-granddaughter of Ernest Giles.
12. NPO report dated 17 December 1956 of a reconnaissance to the Rawlinson Ranges. File 5288 part 1.
13. Memo of 16 January 1956. File 5288 part 1.
14. Memo dated 7 March 1956 from Controller WRE to Chief Scientist W. A. S. Butement. In an exchange of telexes the previous day the Department of Supply had already assured WRE that this monitoring road was indeed essential, and, 'just as much in the interests of the Aborigines as our own'. File 5288 part 1.
15. The assessment of radiation hazard is Butement's, in a memo of 14 March 1956 to Controller

WRE. File 5288 part 1. Dose limits for members of the public were revised downwards somewhat in 1957, before the Antler tests.

16. The Report of the Royal Commission into British Nuclear Tests in Australia, AGPS, Canberra, 1985, provides a wealth of detail and critical comment about the burdens placed on the NPOs during the atomic tests. See particularly pp. 151-74, 299-324, 368-81.
17. Emphasis added. For the historian of the joint project the chief virtue of the NPOs' statements is that they show the inadequate state of knowledge of Aboriginal movements in the far down-range areas in the mid-50s. Of the tribe of fourteen mentioned in the text, only one had seen a white man before. File 5288/1/2.
18. Memo dated 16 March 1956 from Chief Scientist to Controller WRE. File 5288 part 1.
19. Macaulay's 'General report No. 2' dated 7 February 1957 to the WA Commissioner of Native Welfare. File 5288 part 2.
20. Letter of 29 March 1957 from Director of Meteorology L. J. Dwyer to the Range Superintendent Captain I. Newman. File 5288 part 2.
21. Minute dated 15 December 1959. File 5288/1/3.
22. Complaints to the Commissioner of Native Welfare, Perth, dated 10 March 1957, and to the Range Superintendent dated 17 April J 957. The Report of the Royal Commission, p.380, is fiercely critical of this policy and its consequences.
23. Certainly the federal Minister for Native Welfare required urgently to be informed by WRE how 'a Commonwealth document came into Grayden's hands.' Telex from Secretary, Department of Supply to Controller WRE, dated 9(?| November 1956. File 5288 part 2.
24. William Grayden, Adam and Atoms, Frank Daniels, Perth, 1957.
25. Grayden, p.100.
26. The explanation given here is the one offered in an NPO report of 17 April 1957. File 5288 part 2.
27. Letter of 27 April 1970 from Observer-in-charge to the Principal Officer PDA Group. File 5288 part 2.
28. Recommendations from a joint report dated 30 January 1959. Both NPOs were painfully aware of the position they were in. 'The attitude of many at Giles makes the NPO feel and act like a policeman in finding out matters obviously concealed from him. Again, familiarity and overfriendliness in living so closely together makes for difficulty in censuring any offenders.' File 5288/1/3.
29. Report dated 6 January 1960 to the City Coroner. File 5399/1/1 part 1. Additional information from Pat Lonergan, who took part in the search, was supplied to the author in an interview of 3 July 1983.
30. NPO General Report No 5 dated 8 March 1958. File 5288/1/3.
31. NPO report dated 16 June 1960 of the May-June patrol to the Central Reserves and Giles. File 5288/1/3.
32. From NPO report of a joint patrol of the Central Reserve by South Australia, Northern Territory, Western Australia, and WRE Patrol Officers, dated 10 July 1958. File 5288/1/3.
33. Macaulay expressed these views in his paper, 'The Aborigines of the western Central Australia zone of transition', dated 28 August 1959 and given at the ANZAAS conference in Perth.
34. Memos from Deputy Director, Trials Wing to the Director WRE dated 2 August and 5 August 1968. File 5678/3/2.
35. Memo from Controller Research & Development to the Director WRE dated 25 November 1971. File 5678/1/3.
36. Report dated 6 August 1956. File 5288 part 2.



R.D. Jackson with the acceleration camera he helped develop before his summary dismissal.

Peace Officers checking passes at Woomeras' main entrance gate in 1949

7 Guarding the secrets: *The Security System*

A HIGHLY IRREGULAR CASE

One workaday summer's morning in February 1954, R. D. (Bob) Jackson, a temporary Experimental Officer employed by the LRWE at Salisbury, was asked to leave his tasks and appear before the Chief Superintendent, Dr C. F. Bareford. Jackson went along to the meeting happily enough. His work, he knew, was excellent. He had recently helped to design and build one of the Establishment's important pieces of equipment, the acceleration camera, and he had written several technical papers of a low security classification on this device which had circulated within the small world of defence science. Jackson was unquestionably an asset to Salisbury, which was then hungry for skilled and innovative technicians—as it continued to be for many years. It is true that he was 40 years old and after four years' service with the LRWE was still a temporary worker; but that, far from being unusual, was quite typical. Very many people at the time had that status, and some continued to hold it for a decade or more. In the seller's labour market of the early 1950s no one felt it to be much of a handicap, or thought much about the possibility of dismissal without notice which was one of the terms of employment.

But instant dismissal was the sentence passed on Jackson when he appeared before the Chief Superintendent. Bareford told him that on orders from Melbourne his employment was terminated. He was given no opportunity to defend himself. In fact he hardly said a word. In the company of two security officers he was marched down to his office, where he emptied his filing cabinets and surrendered his papers, his keys and his half-completed work. He was not allowed to collect his car. In his own recollection he was escorted to the front entrance to the compound and ejected on to the dusty roadside. Behind him the gate slammed shut. Had not an acquaintance driven by and given him a lift, he would have had to walk home. The whole brutally sudden process—trial, judgment and execution—had been deliberately planned to take less than two hours.

A few days later Jackson's car was returned to him bearing signs of a thorough search. Five days later he received the sole explanation he ever got from the authorities. It told him in one sentence that his services had been dispensed with under section 82(6) of the Public Service Act—a section which dealt with conditions of temporary employment, not security. The security aspect was never mentioned in writing, and yet it was the reason for the dismissal. The Department of Supply had taken at face value an assessment by the Australian Security Intelligence Organisation (ASIO) that Jackson was a 'communist sympathiser', even though that assessment was apparently based on unsubstantiated reports from a single informant.[1]

It should be said at once that this was an extremely anomalous, indeed probably a unique, case which can only be understood in the light of some other facts which will be mentioned later. It was also a product of the times and of the rawness of the Security branch in the early 1950s. Nothing like it could conceivably have happened in later years. Nevertheless, it is a salutary reminder of what might happen to an employee of the joint project if he or she fell foul of the powerful organisation set up at Salisbury and Woomera to protect the 'national security'.

National security is a concept about which most people have ambivalent feelings. They know that every country protects itself against espionage and that even in the most open democracies citizens are not privy to all kinds of secrets, especially those of military technology. The majority accept this principle, and yet cannot help feeling some distaste for the actual machinery of security: the guards, the fences, and the spot checks; the passes and the interviews; the rituals of safeguarding documents; the inflexible and sometimes stupid bureaucracy which goes with it all. When the long range weapons project began, very few of its new employees had ever had anything to do with guarding state secrets. Up to this time Australia had not had a great many secrets to protect. During the war the services had their own intelligence departments, and these naturally listed counter-espionage among their duties; but very few civilians had ever been involved in classified work, and certainly in nothing on the scale of the joint project. Now here was the need, all of a sudden, for the meticulous day-by-day control of documents and equipment whose secrets, if leaked to a foreign power, could cause appalling damage to the defence plans of the Commonwealth.

AUSTRALIA ADDRESSES BRITISH APPREHENSIONS

The British Ministry of Supply had strong views about the existing security measures in Australia. It regarded them as intolerably lax and superficial. The Ministry had a point. No effective legal machinery existed to deal with potential spies or with the leakage of secret information. Australia had nothing like the British Official Secrets Act, which dated back to before World War L It did have section 78 of the Crimes Act, under which people could be prosecuted for communicating classified information, or for approaching a prohibited place; but in any prosecution the Crown had the difficult job of proving that the defendant was motivated by 'a purpose prejudicial to the safety or interests of the Commonwealth or any part of the King's Dominions'. The Act said nothing about charging people or dismissing them from employment merely because their integrity or contacts were thought suspicious. Nor could it be used against journalists who revealed secret information, unless it could be proved that they had done so with the deliberate intention of damaging the State. The British were most unhappy about the provisions of this Act, putting as it did all the emphasis on motives rather than consequences. Evetts was shocked to find that even the details of what the organisation intended to do about security appeared, as he put it, 'in blazing headlines in the *Age*, the *Sydney Morning Herald* and the *Melbourne Herald*'. He commented:

> these three papers have made blatantly public a subject which we wanted to keep quiet. Can no steps be taken to stop this sort of thing in future? Is it possible to deal with the Press in the way we do at Home by means of the 'D' notice?[2]

The 'D' notice system, whereby the press can be given information but agrees not to publish it, was unheard-of in Australia at the time, but the government dutifully took heed of how they managed these things at 'Home' and promptly introduced it, along with a flurry of new legislation: additions to the Crimes Act and the Supply and Development Act, and two other new Acts. The amendments of 1948 to the Supply and Development Act gave to Peace Officers (the forerunners of the Federal Police) the right to search and arrest staff entering or leaving establishments such as Salisbury. The draconian Approved Defence Projects Protection Act has already been mentioned: essentially it was intended to prevent labour agitation at Woomera. The Defence (Special Undertakings) Act of 1952 was passed with the requirements of both the joint project and the program of atomic testing in mind.

Contrary to popular belief, it is not the job of a Security branch to catch spies. That became the job of ASIO after its creation early in 1949. Rather, Security exists to make life hard for the spy. Its functions are essentially passive: to limit access, to supervise the classification of documents, to check, guard and control. At that time in Australia there was only one government agency capable of taking on such work. This was the Commonwealth Investigation Service (CIS). CIS was a section of the Attorney-General's Department, and had about 100 staff under its Director, E. E. Longfield Lloyd. Hitherto in its short life—for it had only been created at the end of the war out of two earlier organisations—CIS's work had been limited to administering the Peace Officers, looking into cases of counterfeiting, chasing debts owed to the Commonwealth, vetting applicants for public service jobs, and compiling dossiers on communists and other dissidents. Now the new and considerable task of administering defence security fell on its shoulders. In September 1947 a special budgetary allowance of £14 700 allowed it to expand its staff with sixteen new recruits, most of them young men with military backgrounds who typically had had experience in Intelligence or Field Security work.[3] Under the first head of Security at Salisbury, William Sumner, officers were posted to the LRWO and in fact had their fares paid to go out to

Salisbury from Adelaide each day. A few years later in June 1950 the Security officers were detached from CIS, becoming instead employees of the Department of Supply. CIS was itself absorbed by ASIO and the Commonwealth Police.

Right from the earliest days Security had many tasks to fulfil, and some of them reached far beyond the South Australian borders. The Supply headquarters in Swanston Street, Melbourne, had to be made secure, and where work was being done extramurally by universities and firms their employees had to be supervised and as far as possible 'kept in ignorance of the significance of the tasks on which they are employed'.[4] Then it had to advise on the shipping of stores and equipment from Australia to Britain, and on moving them around in Australia. It had to establish safe loading zones at harbours and airports and even, if necessary, arrange camouflage, clandestine movements and disinformation. It had to formulate rules for using telephones, radio transmitters, telegrams, teleprinters and the mail. It had to obtain encryption and scrambling equipment and train people to use it; eventually a coded communication service connected most Supply establishments in Australia and another linked Defence with the Ministry of Aviation in London. It had to start up a system for moving highly classified documents around the country. This was the 'Safe Hand Bag' service. The document was placed in two envelopes; the inner one sealed and the outer one giving no information about the contents but containing a receipt to be returned to the originator within a set time. These packets were carried in locked and sealed canvas mailbags by couriers—usually Peace Officers. Those sent interstate by air were handed into the personal care of the pilot and met at the destination by another courier. Very sensitive documents were sent to and from Britain in the Diplomatic Bag. The Safe Hand Bag system allowed one security man working in London to receive immediate news of the birth of his daughter by official telex. The innocuous message read 'Bag arrived safely 29 August'. In the ensuing celebrations it came out that the code for the birth of a son would naturally have been 'Mailbag arrived safely'.

The chief duty of Security was to vet the hundreds of people who were applying for work at Woomera or Salisbury. Such checks were necessarily of a basic kind, for the records were dispersed and the manpower short. The assistant inquiry officers who did these checks put in a good deal of legwork as they went around in person scrutinising CIS and police files, following up character references and checking births, marriages and deaths entries. Most of these checks produced nothing of import, and the assessment by the officers' superior was able to say in the official rubric 'nothing of an adverse nature is known or recorded'. However, quite a proportion of the Woomera workers, especially the Woomera West labourers, did in fact have a police record: for such things as riding a bicycle without lights, being drunk and disorderly, or, a popular crime, urinating in a public place. A minor criminal record was not in itself enough to cause rejection by the LRWO. A labourer working on a road gang, even if he had been in jail for larceny some years before, was not necessarily barred from Woomera: an applicant for an accountant's job, on the other hand, would be. In the case of people with backgrounds interstate, checks were made via the CIS departments in the other capital cities. Again they were rather rudimentary, relying for the most part on the personal particulars form which each applicant filled in. About the most that was done in a routine way was checking a person's signature against the electoral roll. No systematic attempt was made to gain information on political or ideological sympathies, though when the police check was done this automatically included a check of the files on dissidents held by the Special Branches of the state police forces. Cases of people being expelled from Woomera for security reasons were very rare indeed, though a number were filtered out at the vetting stage. (For example, in the eight months between November 1948 and June 1949, fifty-seven applicants were not hired because they received adverse reports.) Really thorough vetting was performed only on those who were going to be privy to the most vital secrets, and since these were mostly British at first, they arrived in any case with a clearance from MI5. Conversely, Australian clearances were accepted without demur by the British.

The migrant workers, the so-called 'Balts', presented Security with a major headache. Fresh from the chaos of Europe and with every incentive to conceal their past activities, the Balts posed an insuperable problem for those trying to check their political allegiances. Practically all the migrants were outwardly animated in their contempt for both Fascism and Communism. The true Balts from Estonia, Lithuania and Latvia had all seen their homelands invaded and annexed by the Russians and then, when the Russians retreated in 1941, the Germans had moved in and sent thousands of them to the Reich as forced labour.

The Yugoslavs, most of whom had fought first the Germans and then Tito's partisans, were fanatically anti-communist, and so were the few Ukrainians. Nevertheless, the possibility of deception did exist. Immigration department records and their overseas offices supplied some information, but its reliability was questionable. Mostly Security had to deal with the Balts at Woomera as they found them. In theory it should not have been too difficult, for the official edict was that no alien or 'New Australian' should be allowed anywhere near the ranges, Evetts Field or classified material. Since very little was sensitive in those early days other than documents, it should not have mattered much what their political sympathies were if they were only doing rough labouring work. In practice, though, many of the Balts had invaluable skills. A capable draughtsman was worth his weight in gold and it is not surprising that a harassed Works foreman was far more interested in a man's talent for drawing a front elevation than his political sympathies. Thus, to the despair of Security, Balts kept finding their way into Technical Area offices. Security's concern was by no means misplaced. As one officer pointed out, it was slightly absurd to be spending time on some minuscule communist activity in Port Augusta when at the Range 'we actually have Aliens employed on a top British Empire Defence Project corresponding direct to countries under Russian or Communist domination'. Amazingly enough, at least three Balts at Woomera were writing openly and regularly to addresses in the Soviet Union![5] A certain point was given to this comment when letters from Poland started arriving at Woomera franked with slogans exhorting the reader in French and Polish to give up the arms race before humanity was destroyed. Whether this was a propaganda exercise aimed specifically at the Range workers or part of a broader campaign was never ascertained, although ASIO looked into it.

Apart from the vetting of personnel, most of the emphasis fell on simple physical measures intended to control access. Salisbury was the greater risk. The site was dispersed and it held the most secret data of all—the records of trials performances. So fences left over from the munitions factory days were relocated and reinforced, and supplemented with boundary wires, internal alarms and regular patrols by the squad of twenty Peace Officers. The air navigation regulations were altered to make it illegal to fly low over the site.

The single most effective innovation was the use of trained guard dogs. A few dogs were kennelled at Salisbury from the beginning, but they were untrained and useless, except

Senior Constable Mason Clark (*right*) conducting a guard dog handlers course, with Constable Lee of Christmas Island. (Adv) as a noisy and probably unreliable deterrent. The Peace Officers hated them and referred to them scornfully as 'the bloody dogs'. At that time in Australia even the police forces knew little or nothing of the art of dog handling and tracking. But in 1950 the Establishment obtained the services of a Peace Officer, Mason Clark, who had acquired the skills in Europe. Clark had escaped from an Italian prison camp and had spent the rest of the war interned in Switzerland, where he became interested in training German Shepherd dogs for security and tracking work. Under his guidance the mangy and half-wild pack at Salisbury was properly bred and culled, and the mistrust of the Peace Officers was eventually overcome. Clark knew he was succeeding when he overheard an Officer refer with casual pride to 'our dogs'.[6] Around the hundreds of Salisbury's buildings on a dark and dirty night the dog and guard team made a formidable combination. On regular patrols the dog was sent circling a building while the guard checked the locks. Or it could be sent ranging through a building with its maze of workshops and laboratories and return an absolute assurance that no one was within. If it found an intruder or, as actually happened sometimes, an employee working late, it was trained to keep at a distance and attract the guard's attention by barking, for even a German Shepherd dog is by no means invulnerable to a determined man's stick or boots. (On the other hand they were trained to attack and to keep on attacking a man with a pistol, since the guarding stance made them an easy target.) Clark and his gifted tracker dogs Dawn and Chrissie became local celebrities, for they were often called to other parts of the country to hunt down wanted men in the bush or to trace lost children. The resulting publicity served the Establishment well and, together with the frequent public displays of fearsome if simulated dog-attacking methods, is doubtless the reason why, as far as is known, no intruder ever got into Salisbury. With evil intent, that is to say. Children sometimes penetrated the fence, and on one occasion an officer waiting just inside the gate was hailed by an elderly couple in a car. They wanted to get to Elizabeth but couldn't find their way out. How they had got in they couldn't quite recall.

At Woomera the sheer size of the ranges made it impossible to seal them off physically, but the Commonwealth did the next best thing by amending the National Security (Munitions) Regulations so the surrounding region could be declared a prohibited area. At first this was a distorted rectangle of some 32 by 64 kilometres, with its boundaries skirting the east-west railway line to the south and Roxby Downs and Purple Downs homesteads to the north; later, it was much expanded. Entry to the village, and still more to the Range, was tightly controlled by checkpoints and passes. Every family member coming to live at the village received a lengthy briefing on the perils of speaking out of place. The most resented edict was that no cameras could be kept at home; they had to be checked in and out of store. As one early resident recalls indignantly: 'You couldn't even take snaps of your children. You had to ask for your camera back if you wanted to film a birthday party. It was ridiculous and petty; as if there were any sensitive sites in the village!'[7]

Yet, apart from these routine measures, no real thought had been given to the role the security officers should play during their four-monthly tours of duty at Woomera. One man, for example, was attached to Major Morrie Bennett's No. 1 Line Construction Project Squadron far from the village. 'Just sort of watch the place', he was told. 'Keep your ear to the ground.' He has since recalled:

> I didn't know whether I was listening for stampeding elephants or looking for communists under every rock. In particular I had to keep an eye on the road from Woomera to Koolymilka. I didn't know whether I was supposed to check that they put the right depth of limestone on the foundations of the road or what. I spent months at Woomera with no clear briefing as to what I was supposed to do. I went back to my office in the village one day and the Range Security Officer asked what I was doing there. I said, 'I've just come to town to check on things.' 'Oh', he said, 'well, you better hurry up back to Kooly then.' So I had to hurry up back, to doing nothing again.

'Nothing' is an exaggeration. Bennett's men worked the peculiar hours from three o 'clock in the morning to noon, after which it was too hot to do anything. The officer got up with the others since he couldn't sleep anyway, and, lacking the opportunity to exercise his professional functions, spent his day with his shirt off digging post holes with everyone else.[8]

For work in the field the security officers were issued with a heavy double-breasted trenchcoat. In this unlikely garb they stalked about the Range like so many Humphrey Bogarts, yet the job had little glamour—it was boring and sometimes unpleasant. Relations with the residents and the construction workers in those first days were not good, and Security's particular thorn in the flesh were the young scientists and engineers themselves. Fresh from university life, and aided and abetted by some of the more senior staff, they were articulate enough to make their resentment unmistakable, perhaps because they suspected correctly that undercover agents were planted among them.[9] They rejoiced in silly jokes like planting 'classified' material with Secret stamps all over it in wastepaper baskets, or voicing mock concern that the first Peace Officer on duty in the morning had no one to show his pass to. The men of one workshop even complained that loose change and snacks had started to go from locked drawers overnight, and they retaliated by placing a large capacitor highly charged with electricity inside an inviting lunch bag. It was not long before this booby trap was found discharged in the morning, having given someone a very nasty surprise. In short, a common opinion was that some of the Security men's own motives were suspect; that they were licensed to be professional snoopers and nosy parkers, and that their view of the world verged on the paranoid. Such attitudes fed the rumours that officers were stationed in Salisbury pubs armed with little notebooks in which to jot down details of unguarded conversations. While this was no more than rumour informers were certainly used, and sometimes of a most dubious kind. In a Woomera West mess, for instance, a labourer was overheard confiding drunkenly to a friend that he had a work called *The Private Life of Joe Stalin* in his quarters. The informant, who himself admitted having taken drink at the time, passed this revelation on to Security, which took it seriously enough to suggest that the group of three friends, all unionists, should be revetted.[10] When people heard of such incidents on the grapevine they came to feel, not unnaturally, that Security itself was the enemy, a spy force trying to catch them out in some indiscretion, and this made them jittery and obstinate. One ex-officer well remembers the trouble such attitudes made for him:

> I got a document one day which was a plan for a three seater latrine—just a wooden shelter over a pit. It had been classified Secret. I went to the engineer who classified it and asked what was secret about it. He said: 'Ah—because it's in the Technical Area.' 'But it's nothing but an earth latrine!' I protested. 'Oh, yes, but it's in the Tech Area and everything going in there has to be classified.' Now this was the thinking of a professional engineer. The fact is, people were alarmed, over-reacting: we'd never been properly briefed and we didn't know what the risks were; we were fearful of making some horrible blunder.[11]

Some of the excesses produced by this fear had nothing directly to do with Security, which tended to be the whipping boy for all sorts of administrative oddities. One of the young scientific trainees was given the job, soon after his appointment, of writing a simple report on the 'state of the art' in computers. This was more or less a test exercise, and he drew his material from sources no more private than the books and journals on the shelves of the Adelaide University library. To his astonishment and amused disgust when he submitted his report it was at once seized, classified Secret and vanished forever into limbo.[12] Security itself cannot be blamed for this response, for it did not have the duty of classifying documents. The story suggests, however, the prevailing mood of nervousness and undue caution. For the most part the security officers were themselves young and untrained; there was no one to train them at first. They used a little British booklet issued just after the war, and from it evolved their own manual of practice, familiarly called SOOD&I (Security of Official Documents and Information). Later on in-house training programs and lectures from ASIO were introduced, but in these first years the blind had to lead the blind as best they could.

These rather bumbling first efforts at security should not obscure the facts that much was at stake and that Australia's initially casual approach was regarded somewhat balefully by other countries, particularly the United States. It is necessary as usual to look at the climate of the times. This was the era of the 'super spy', when crucial technical secrets were passed to the Soviet Union by men and women of great ability who committed acts of treason for ideological reasons—or who did so at first anyway, before they were inextricably ensnared. They were extremely difficult to catch. The years of Woomera's establishment and first work, roughly 1947-55, were also the years when a number of British spies were active, some of them in overseas countries and occupying high level posts. As the joint project began, still fresh in memory was the unmasking of a genuine spy ring in a Commonwealth country, Canada, which had only come to light with the sensational defection of the Russian cypher clerk Igor Gouzenko in September 1945. One of those subsequently convicted was the Englishman, Dr Allan Nunn May, who had been arrested in London in March 1946 after a spell at Chalk River, the Anglo-Canadian atomic research facility near Ottawa; he had also visited atomic research laboratories in Chicago after the Americans had trustingly accepted his British clearance. In the summer of 1949 American intelligence became aware that a spy had been at work in their atomic research establishments during the war. When he was arrested the following year, Klaus Fuchs, a German-born British scientist who had been privy to secrets of great importance, had completed seven years of active spying for his Soviet masters. That same summer of 1950 a Harwell scientist, Bruno Pontecorvo, quietly vanished with his family behind the Iron Curtain after a career spent partly at Chalk River. The following year saw the defection to Moscow of the infamous Burgess and Maclean, after postings to Washington where they had done incalculable damage to their host country's interests. It is hardly surprising that even before these cases broke some Americans were concerned about the security of a 'third party' country, which was how Australia was regarded. If the British and Canadian methods of vetting possible communist sympathisers and potential spies were slack to the point of incompetence, were the precautions likely to be more stringent in easy-going Australia, far from the centres of power? They remembered that the British had already shown few scruples in passing on secret information to a friendly foreign power. After the liberation of France in 1944 French scientists had worked alongside Britons at Chalk River and had inevitably been privy to vital nuclear secrets. One of these French scientists was the brilliant Frederic Joliot-Curie, to whom de Gaulle quickly gave the responsibility of directing the push towards a French bomb. And Joliot-Curie had joined the Communist Party during the war.

Some Australians, too, were eager to expose the flaws in the security provisions, and in 1947 the subject appeared repeatedly in the headlines and the columns of H*ansard*. A Country Party MP, J. P. Abbott, demanded a Royal Commission to inquire into 'certain people'; more specifically, into the personnel of the Australian Association of Scientific Workers and their links with the Communist Party, and into known communists employed by CSIR. Various names were bandied about, with a call that their dealings with the Soviet Legation should be investigated. Something sinister was seen in the fact that Australia, whose diplomatic relations with the Soviets were supposed to be minimal, nevertheless had a Russian delegation of sixty-three persons, 'as big as all the rest of the other countries' delegations put together'.[13] Most of the disquiet centred on CSIR, because, it was alleged, there was a 'close association' between some CSIR officers and the Communist Party. The name of CSIR chairman Sir David Rivett repeatedly came up in this connection, and the constant harassment he suffered in Parliament and the media is said to have made him ill and forced his premature retirement. No doubt some joint project scientists like their counterparts elsewhere went further and sincerely believed that the cause of peace would best be served by making sure that the Soviet Union, lately an ally against Fascism, was not left behind in the race to perfect atomic weapons and missile delivery systems; that is, making sure, if necessary by 'treasonable' acts, that the balance of power was preserved. At the trial of Nunn May his counsel had used the analogy of a medical research worker, who is right to feel morally obliged to publish his findings internationally even if there would be considerable profit for a country or firm holding a monopoly in a new drug or treatment. Some elements in the British Association of Scientific Workers certainly sympathised with this point of view, and they had twice called for a reduction in the gaol sentence imposed on May. Such feelings were paralleled in Australia. There, the government itself was widely perceived to be lukewarm in its willingness to investigate whether any scientists' loyalties were suspect. The somewhat beleaguered Minister for Defence, John Dedman, said reasonably that many scientists had communist leanings, and that out of CSIR's five thousand employees there might be a few party members, but he was absolutely sure none were connected with defence research. At this time, Dedman informed the House, the CSIR was undertaking no secret work at all, but that would be changing shortly when it took on joint project work which could not as yet be done elsewhere. This information would hardly have sounded reassuring in some quarters although, as we know, it never did any such work. Furthermore, Dedman's bold assertion that he was 'perfectly satisfied' with the current security arrangements caused him to be savaged by even the moderate press, which found 'no limits to the complacency' of this 'incurably apathetic' Minister.[14]

Behind the scenes the government was being far from complacent. Early in 1948, when it was planning the creation of ASIO, it had invited advice from Sir Percy Sillitoe, Director-General of the British Security Service, and two of his staff. All were experts on groups regarded as subversive. As a result of their recommendations basic security measures were noticeably tightened up, and journalists noticed that when a party of ministers and others visited the Range soon after Sillitoe's group had returned home every one of them was sporting a pass, including Evetts himself. The Opposition was by no means satisfied,

Sir Percy Sillitoe. (Topham)

however; Abbott alleged in Parliament that Sillitoe had been so appalled by what he had seen of Australian security that he had refused to release his devastatingly critical report to anyone except the British Prime Minister. However, no such report has been traced. It may have been made orally.

Of course the Opposition was keen to make political capital out of the failings of Security. Yet for all the rhetoric there was real reason for disquiet. As early as 1947 sources inside the joint project itself were guilty of a series of indiscreet statements and downright leaks to the newspapers about present and planned projects. These leaks, made for unknown motives, included information which had apparently been taken directly from the minutes of the Board of Administration meetings. The potentially most damaging item was a report that the British were experimenting with astro-navigation guidance systems. This was the case; at this time finding a way of giving a missile an accurate and unjammable means of directing itself to its target was the most eagerly pursued problem in guided weapons research. Dedman's private opinion, expressed to a fellow minister, was that this revelation especially 'would increase distrust in the safeguarding of secret information in Australia, and may have a serious effect on the readiness of the United Kingdom and the United States to furnish information to Australia'.[15] Dedman was not given to scaremongering, and his comment perhaps suggests his awareness that the leaks had not gone unnoticed outside Australia.

THE AMERICAN EMBARGO, 1948–49

The most remarkable illustration that this was indeed so was a circumstance which, fortunately for the Chifley government, was never aired in Parliament or the newspapers. On 1 July 1948 the Head of the Australian Military Mission in Washington was formally advised that Australia would receive no more classified information from the United States. Later the same month came confirmation that this edict also applied to information coming via another country, for the Director of the UK Signals Intelligence Centre had to advise Melbourne that it had been forbidden to pass on US secrets to which it was privy. Just as unwelcome and embarrassing was the news that henceforward none of Australia's joint project trainees could be taken into the defence establishments of the United Kingdom. This aspect of the embargo was by all accounts a bolt from the blue. The Australians were taken so much by surprise that one group of trainees was left cooling its heels at Salisbury practically on the eve of their departure, and the confusion lasted so long that a few finally gave up in disgust and paid their fares to England out of their own pockets. Some others of the group who had already arrived in London were put on ice at the Ormond Hotel in Belsize Park for weeks on end while their new destinations were hastily worked out. The problems were so formidable that, according to one trainee, he and his fellows helped to make their own arrangements to start university courses or to get into other non-sensitive institutions.

What stood behind this astonishing embargo? Clearly the British were not acting of their own volition. They had little choice but to impose it, for the United States had made it plain that classified information would no longer flow to them either unless they redefined Australia as a 'third country', or one without a special relationship with the US. What triggered the American action is not entirely clear. There may have been no single cause, although the immediate push came from the Office of Naval Intelligence. Diplomatic relations between the United States and both Britain and Australia were cool at this time. In some Washington circles it was found incomprehensible that the British electorate had rejected a Tory Party headed by Churchill, the man who had seen them through the war, for the Labour government of Clement Attlee. They were wondering uneasily how far the country was going to swing to the left and whether it would continue to be a firm ally in the emerging cold war. There was irritation, too, at the delayed announcement in May that Britain was making an atomic bomb, relying in part on US data garnered before (and, some suspected, after) the McMahon Act came into force in 1946. But America was still enjoying better diplomatic relations with Britain than with Australia. Here relations were chilly indeed, not least because of the determination of the Minister for External Affairs, H. V. Evatt, to take an independent line in foreign policy. From some American perspectives the Australian Labor government was being unsupportive over Japanese and German policies, over Greece and Indonesia, over the United Nations and the Soviet Union. It expressed itself hostile to economic imperialism and seemed wilfully blind to the menace of Communism in Asia.

However, in imposing the embargo the Department of Defense had more specific grounds for complaint than this. It cited the 'unsatisfactory security situation' in Australia.[16] The 'security situation' there was found wanting in two main respects: first, there was the perception of an undue influence of Communism in the affairs of the Labor government; and second, US intelligence agents working in the country had reported that classified information was being leaked direct to Moscow. Indeed, the gossip in Washington was that the Soviet Ambassador to Australia was boasting freely in Canberra that he could obtain information on any subject he desired. It turned out months later that these claims did have a certain substance, as an Australian espionage investigation was forced to concede in March 1949:

> It is known that there is in existence in Australia a Soviet spy network which has, or had, means of obtaining information from Australian government departments. Two of the agents of the network have been identified. One worked in the Department of External Affairs and is known to have passed information to the Soviet intelligence machine which was available to him as a result of his work. The other worked in Dr Evatt's private office and, though not engaged on secret work, may have had access to official material. Neither of these two agents is now employed in any Australian Government Department . . . As far as is known there have been no leaks from Defence or any of the Service Departments; nor is it known if any information of a secret scientific character has been passed on to the Russians. The identifiable leakages from the Department of External Affairs are reasonably attributable to the two identified agents mentioned above.

The report added that getting sufficient evidence to prosecute successfully was extremely unlikely, because the leakage dated back to 1946.[17]

The Americans accepted that no military secrets had leaked but they made it plain that, much as they regretted it, the embargo would stay in place until they were persuaded that Australia really had improved its performance. They feared that technical secrets could not be restricted to military officers and scientists but must inevitably become available to politicians. The ideological sympathies of some of these men—certainly Evatt, perhaps Dedman, even Chifley himself—were a matter of dark suspicion in some quarters. Their Ambassador in Canberra was left in no doubt that Washington found the easy promises of Dedman, Evatt and others less than convincing. As the uncompromising and staccato text of a US State Department cable to the Embassy put it at the end of 1948:

> Your reports deepen impression there has been much delay meeting situation and tendency part Australians seek concessions our part before they have made substantial plans or progress. For your information there is no repeat no likelihood early or substantial change in policy of limiting exchange of classified material with Australians. Any change will require more positive and successful action their part than so far demonstrated.[18]

There is no doubt that this tough attitude precipitated a serious secret crisis in American-Australian relations. It was a bitter blow to the pride of the Chifley government, for Australia had now been relegated to 'Category E' as a recipient of information, that category being the lowest among all the nations with diplomatic representations in Washington. The British could do nothing to help. Tizard was allowed to make representations towards the end of 1948 to have the embargo lifted, but to no avail; in February 1949 while visiting Australia he was obliged to report to the Board of Administration that despite his best efforts it would be continuing indefinitely. Evetts, among others, then urged the benefits of seeking a compromise—restoring the flow of the most crucial technical data to the project—but Chifley refused to entertain this for a moment. As the influential Secretary for Defence, Sir Frederick Shedden, put it indignantly:

> We are not importunate bankrupts who would be content with a certificate of discharge for ten shillings in the pound, when we know that we are entitled to a full discharge based on our past record of defence co-operation in war and peace, the commitments assumed under the present programme, and the measures taken for the protection of defence information.[19]

For Chifley the embargo was a political matter in which the reputation of his government and his country was at stake. He wanted the 'full discharge' or nothing; he could not be expected to weaken his case by taking the heart out of it.

After lengthy and cautious preparations Sir Frederick Shedden went to Washington in April 1949 to take the matter up with President Truman and Dean Acheson, then Secretary of State. The latter recorded the gist of one discussion in a memorandum.[20] Shedden reminded Acheson that Australia might only be a small nation of eight million but it was spending a great deal on defence in the Pacific region; something which was to the obvious advantage of the United States. It was also putting strong efforts into guided weapons research at Woomera, yet Australian scientists had, as he put it, ‘run into a road block’ in getting the external training they needed to work effectively there. He assured Acheson that leaks were now a thing of the past and as soon as ASIO was functioning properly Australian security would at least be on a par with the British. Acheson repeatedly questioned Shedden about when that would be, but without getting any answers that struck him as satisfactory. Presumably this line of questioning reflected the Administration’s view of what was required of Australia before it could think of lifting the embargo. Certainly the Americans were less than impressed when Shedden presented the LRWO Security Plan, an elaborate document designed to remedy the deficiencies at Woomera and Salisbury. Doubtless its authors would have been mortified to learn the opinion of the US Ambassador, Peter Jarman, that it was less a set of working instructions than ‘an assemblage of related material for the instant presentation’: in other words, a piece of window dressing! Another thing that produced unease in Washington was the fact that the temporary head of the new security service was Mr Justice Geoffrey Reed, on leave of absence from the South Australian Supreme Court. As the Chargé d’Affaires at the American Embassy put it:

> Mr Reed is a patriotic Australian of the highest integrity. Misgivings have been privately expressed to me, however, by several Australians on the ground that he is inexperienced in this very complicated field, that he is not noted as an administrator, and that he probably lacks the ruthlessness required in the operation of a security service.[21]

So the embargo stayed in place for the rest of 1949. As the months passed, though, different shades of opinion emerged over the wisdom of maintaining it. LRWE was not without its American friends. One of them was Commander Stephen Jurika, the naval attaché at the Embassy who later described himself as a terrific barracker for the project. He visited the Establishment several times and mulled over the matter with Evetts, later reporting back to Naval Intelligence stressing that ‘the Commonwealth Government is very much concerned with American denial of information to their trainees and they would be prepared to go to almost any length to remove these restrictions’. If the embargo continued, he thought, the consequences might be very serious indeed:

> The LRWE will of necessity have to fold up if the long range plan for training young scientists in the UK is not effective. As mentioned, Britain cannot supply herself and Australia too. Such action would redound to the discredit of the Commonwealth Government and create such a furor among the people that: (a) the Ministry in power would topple; or (b) anti-American feeling would be whipped up (by the Government’s Department of Information and control of all broadcasting) to fever pitch . . . I know for a fact that Dedman (Minister for Defence) and certain other Ministers hold a deep feeling of resentment against the United States for its attitude on Australian trainees. It may well be that, among other reasons, this is the cause of delaying tactics and irritating little hazards placed in the way of several treaty consummations.[22]

Jurika’s assessment of the level of resentment in the Australian Cabinet was accepted by his superiors as correct, but the State Department took the robust line that while it would be deplorable if the embargo dealt a death blow to the joint project this was not ultimately a reason for changing the policy.

The actual consequences for the project were a good deal more modest than in Jurika’s alarming scenario, but that may only be because they had little chance to manifest themselves since the embargo lasted just a few months longer. While it was in force it certainly generated much discontent among the trainees, for it was the rosy prospect of overseas training that most encouraged the talented ones to take up military work. The grumbling reached such a volume that an Inquiry Officer was given the job of canvassing opinion among the stranded trainees and preparing a report on it. One trainee forthrightly recorded his view that the Establishment was treating him and his fellows like children and instead of acquainting them with the real political position was ‘putting them off with a mob of lies’.[23] It was plain that since some of the trainees were already receiving attractive offers from private firms something had to be done soon, otherwise the most capable ones would be lost. One ruse, proposed at quite a high level, was to rename the trainees ‘Junior Scientific Members’ to disguise their real status and then pack them off to Britain as Liaison Visitors. Something more realistic emerged from discussions between Chief Scientist Butement and Sir Ben Lockspeiser. They realised that the problem could at least be alleviated by placing the embargoed batch of trainees into suitable British universities as graduate students. This was done, and with considerable success. Still, this solution could only be a stopgap measure. Universities could not offer the kind of specialised and classified work available at establishments like Farnborough, although as it happened some trainees got the best of both worlds by first doing their graduate courses and then working briefly in Supply research centres after the embargo was raised, before returning to Australia.

Apart from its obvious effect on the trainees, the American ban on giving Australians access to British-held defence secrets had only patchy results. Certainly it was taken seriously enough in some quarters. One trainee arrived at the National Gas Turbine Establishment at Pyestock where his room mate was an American from the Applied Physics department of Johns Hopkins University. One day the American visited his embassy in London, where he unwittingly mentioned that an Australian was sharing his quarters. He was instantly moved away.[24] On the other hand, Australians already working alongside Britons were not affected at all, even those working for the Ministry of Supply on guided weapons at the highest and most sensitive levels. Probably the British were less than zealous in applying the measures against their colonial cousins who were after all a source of fresh and capable brainpower. That June, in fact, the US National Military Establishment addressed an aide memoire to the British government complaining that certain information about VT fuzes, which had a joint origin, had been passed on to the Australians. The British refused to be flustered by this charge. Possibly they had committed a minor infringement of the letter of the security agreement, but they insisted they were still adhering closely to its spirit.

As 1949 drew on, though, the situation became ever more tense in Australia. William Coulson, the Munitions Representative in London, was English by birth. He suggested that he should take a 'demi-official' position inside MoS (presumably with its connivance) as a consultant on explosives. Then he would be wearing two hats. 'With my English hat I could attend meetings and see "discreet" papers and with my other hat I could watch Australia's interests.'[25] His scheme was not taken up, but the fact that a senior Australian official was prepared to recommend a measure that he frankly admitted involved subterfuge suggests how serious matters were becoming. What made things worse was that the Americans preserved an obdurate front, refusing to concede that they were becoming any happier at all with the efforts Australia was making. Right up to the last minute the government was allowed no consolation that the issue was nearing resolution. During his leave in the UK in 1949 Evetts had prolonged discussions on the matter with his masters, and he reported the gist of these to the Board of Administration in November 1949. His remarks were veiled and allusive, but he could not be accused of taking matters lightly:

> In view of the delicacy of the situation I feel unable to say more at this meeting than that it is quite clear that the solving of this particular problem is an essential pre-requisite to the solution of many of the other matters already referred to which have caused some doubts about the Ministry of Supply's outlook upon the Project here. I would like to say, however, after hearing and seeing so much of what has been said and written on the subject, that my personal opinion is that the *solution lies more in Australian hands than elsewhere*. Unfortunately while the present impasse continues it is impossible to proceed with the original training scheme without causing incalculable harm to the interests of Australia as well as the United Kingdom and indeed the British Commonwealth as a whole.[26]

But the LRWE was not to be kept on tenterhooks for much longer. The embargo on trainees was lifted at the same time as the partial withdrawal of the general ban on the transmission of defence and foreign policy information, which occurred as the conservative Menzies government came to power in December 1949. Secretary of State Acheson informed the US Embassy that these events were not causally related and that any attempt for the new government to make political capital out of it should be resisted. He directed that the Australians should be told that Washington and the military establishment were now satisfied by Shedden's quarterly reports on the progress ASIO was making.[27] Information above the level of Confidential, however, continued to be embargoed, and rumours about American dissatisfaction did linger for some time, despite the fact that by the middle of the following year Australians were helping to fight communists in Korea. Even at the end of 1951 the rumour was still abroad that the US was withholding vital data on guided weaponry from Britain because there was 'too much Communist activity in Australia'.[28] This time the rumour was dismissed as 'greatly exaggerated' by Minister for Supply Howard Beale, and it did fade away soon afterwards. The Wilson-Sandys Agreement, whereby Britain and America undertook to pool their research work on ballistic missiles, came into effect around this time and cleared the way for the rapid development of Blue Streak and therefore, indirectly, for the ELDO program at Woomera. When the Americans later brought their own project, Sparta, to Woomera, it was preceded by a close examination of the facilities by officials of the 'State Department'—in reality, from the National Security Agency. The security provisions were accepted without hesitation.

THE SECURITY MACHINERY AT WORK, 1950–80

After it ceased to be a section of the Attorney-General's Department in March 1950 and became instead the responsibility of the Department of Supply, the fortunes of Security Branch slowly improved. In the period 1952-54 there was some squabbling between ASIO and the Branch about the exact spheres of responsibility of each. These had never been clearly delineated. The general arrangement was that ASIO liaised with Supply through its C Directorate's C2 Branch. This was the Branch that investigated all cases of espionage and sabotage in the field of the research, development and production of defence materiel. In South Australia its C2 Liaison Officer kept in close touch with the Regional Security Officer, though it was agreed that within the boundaries of Salisbury and Woomera ASIO had only an advisory role and would take up a matter only when Security had a 'well-founded suspicion' that a case of subversion really existed. What ASIO resented was that Security Branch gradually took upon itself the task of covertly investigating people outside the Establishment. The Director-General soon grew alarmed at the excessive and irresponsible zeal shown by some of the South Australian field officers. He was dubious whether they could ever be raised to the 'required standard' for covert work; for, as he said, the 'SA Regional Security Officer has admitted to me privately on more than one occasion that the standard of intelligence of the greater percentage of his subordinates is not high'.[29]

These rivalries diminished as a total security policy for Australia was gradually codified. One important step was the publication of a Protective Security Handbook issued in the name of the Prime Minister. This manual set out policy on many subjects including the classification of documents, information and materiel. It set the standards of protection to be applied, using the now familiar gradings:

> Top Secret: that which would cause exceptionally grave damage to the nation if disclosed; such matters as negotiations for political alliances, plans for the defence of vital strategic areas, and information about the intelligence services which might imperil agents abroad.
>
> Secret: for instance, information about vital defence establishments and installations, or adverse reports on military morale.
>
> Confidential: material which does not affect national security but which if released might prejudice the interests or prestige of the nation, or cause administrative embarrassment, e.g. documents about individuals.
>
> Restricted: material such as training guides or manuals not intended for public release.

The manual also determined the type of security 'furniture' used to store papers of these various gradings: a Top Secret file, for example, had to be stored in a safe of a certain standard with a five position combination lock of a certain make. By adopting such principles and practice the methods of Security grew less clumsy and more adapted to the circumstances actually found at Woomera and Salisbury. Education programs were introduced, so that new staff were thoroughly briefed on their first day and given refresher lectures from time to time. There were security seminars for heads of divisions and for the managers of the contractor firms; seminars where an ASIO officer led discussions on known spy cases and drew out the lessons to be learnt from them. Gradually people came to recognise how weaknesses in their own workplace might be exploited and how they might be cured, and the scientific, technical and administrative staff grew to accept the principle of individual responsibility for security. At Woomera the presence of Security grew so familiar at last that the residents barely noticed it any more, even though its provisions did regulate their lives. Outside the village, an unobtrusive system took care of most unforeseen circumstances. This was an informal intelligence network using the pastoralists, who quickly learnt when any strangers were abroad in their vast and sparsely populated domains. At Salisbury a new system was introduced. Particular officers were given sole responsibility for advising on the security of the different functional sections: thus, one man was allocated to

Trials, another to Weapons Research and Development, and so forth. These officers made it their business to find out exactly what work was classified, thereby avoiding the need to guard a whole building for the sake of one document in one safe. The divisional heads, who, together with their subordinates, bore the actual burden of looking after their documents, responded well to this system, for it meant they had a man at their side who knew their requirements intimately. The security force, excluding the Peace Officers was still small, though: about seven officers at Woomera (though the Services had their own personnel) and about fourteen at Salisbury. It was not large considering it had to look after several thousand people, especially with the burden of clerical work in administering the pass system. Visitors to Woomera from anywhere in Australia had to have an Identification Movement Form (IMF), which on its issue from an authorised station had to be signed by the traveller. At Woomera a pass was issued and signed for and the guard would check the two signatures. Eventually both documents arrived back at the originator, who would check again. The system was unsophisticated, to put it mildly, and it would not have exercised a spy's wits very much to circumvent it.

The actual classification of new projects originating in Australia was undertaken by a Technical Security Grading Committee modelled on a British counterpart which graded the British weapons tested at Woomera. Classification came only after discussions between the Grading Committee and the originators, to isolate what was new or unique about the weapon—the guidance method, the motor, or whatever. This had to be decided in relation to what was known about other weaponry of a similar nature being produced elsewhere in the world. Protecting the defence interests of the country was obviously the paramount concern, but then and now it is not often realised that something else is at stake too. The production of arms is a commercial venture for governments in that they hope to recoup at least some of the developmental costs by selling the products to others. A weapon that has been kept tightly under wraps is always a more saleable commodity. But imposing good security is never cheap, and the higher the classification the more expensive it is. So throughout the research and development of a particular weapon its gradings were constantly kept under review by the Technical Security Grading Committee to ensure that no part of the project retained an unrealistic classification. For example, the external appearance of a weapon at the design stage might be classified at the high level of Secret because it existed only on paper and so could be easily guarded. By the time it reached the production stage the physical protection required to maintain it at the Secret level might be a wholly uneconomical use of resources, so it would be downgraded. As for documents, these had classifications imposed by the originators in accordance with the current Security Grading List issued for that project by the Technical Grading Committee. In cases of doubt the originator went to the Secretary of the Committee who was an engineer on the security staff. The Committee never gave a single security rating to an entire project. Even in the most sensitive cases each and every bolt never needs to be classified; indeed, as one officer put it, a good deal of information about any secret project could be included in a pamphlet drop over Moscow without doing much damage to the State. An external photograph might not be classified at all if it contained no background features to suggest a scale. On the other hand, the external dimensions might be Restricted and the performance figures Top Secret. While a rocket was being prepared for firing with all its innards exposed, access might be tightly restricted; yet when it was ready or in flight photographing it might pose no risk whatever. Nevertheless, it is surprising what can be discovered from the most humble component. At one Farnborough Air Show a piece of a wave guide carried the caption that it was used with Blue Streak. An alert security man noticed that a few simple measurements and calculations would allow the operating frequency to be determined.[30]

As the work built up at Salisbury in the early 1960s, there was a great growth in the number of documents. In addition to numerous research reports, every weapons project generated at least a planning specification and a trials instruction for every trial carried out—and there could be very many of the latter. Cumulatively these documents numbered in the thousands and each one had to be copied and spread widely through defence offices in both countries. There was a risk of being drowned in a flood of paper, much of it quickly out of date. A Reclassification and Regrading Committee did great work in keeping this down. One year, by coincidence, it dealt with exactly 500 master documents associated with projects whose classifications the Technical Grading Committee had revised. Of these, 499 were downgraded and one upgraded. In the ensuing process of recalling all copies to be restamped with the new grade, most of the recipients declared that they no longer needed them. Not only were departments in the defence group purged of unwanted documents occupying valuable space but literally truckloads of documents were destroyed and dozens of filing cabinets returned to store. In such ways Security grew with the Establishment and eventually merged into its daily work.

SECURITY AND CIVIL LIBERTIES

How effectively Security did its job is, in the nature of things, hard to gauge. If few leakages of information come to light and no malefactors are caught, does it mean security has been so efficient that spies have given up trying, or so inefficient that all the espionage has gone undetected? But however it is to be interpreted, the fact is that the security men of the joint project lived tranquil lives after those first troublesome years. As far as is known no foreign agent ever penetrated the defences at Woomera or Salisbury. A few boastful gossipers in pubs were reported and suitably admonished. Some servicemen from Woomera who had taken to writing their names and units on the menus of the Oriental Cafe in Rundle Street, Adelaide, were told not to. The odd public servant or serviceman chatted to a reporter and later wished he hadn't. On a few rare occasions genuinely classified information did leak to the outside, such as the time when film was left in a filing cabinet sold at auction and the finder tried to obtain money for it from a newspaper. But the finder had no idea what he had got (nothing of much significance, in fact—just some rather old trials film) and the matter was really nothing more than an administrative gaffe. Only one case is known where a man wilfully took papers and tried to sell information. An RAF clerk with the No. 8 Joint Services Trials Unit stationed at Edinburgh airfield was caught in 1958 with classified documents in a kitbag. He was quickly repatriated to Britain, tried and sentenced to a year's imprisonment. No one in Australia was prosecuted.[31]

A few years later speculation about the significance of the clerk's activities was revived by the Skripov case. In June 1959 Ivan Fedorovich Skripov arrived as First Secretary to the Soviet Embassy in Canberra, which had been closed ever since the Petrov affair. Skripov spent more than a year cultivating an association with a woman who became a double agent for ASIO. Then, in December 1962, he gave her a high speed radio sender to be passed to an unknown man in South Australia. The woman kept the appointment in Adelaide but the man failed to show up. After a delay, some details of Skripov's clumsy spying efforts were revealed to the public; he was declared *persona non grata* and expelled from the country. No connection with Woomera or Salisbury was ever demonstrated, but the case is memorable in that from it emerged the only substantial evidence that a foreign power did indeed have an espionage interest in the joint project facilities. ASIO has recently commented that 'it is considered possible that, as penetration of WRE would probably have been high on the KGB's list of priorities, [an] agent may have been operating in Salisbury or Woomera'.[32] If there was such an agent, he or she remained undetected.

Generally speaking the weight of the security provisions lay fairly lightly on workers, apart from the minor irritants to life at Woomera and the constant need to remember passes and lock away papers, and the discouragement of chit chat about one's work. In a few cases, however, the rights of individuals were not guarded as zealously as they should have been. One case, familiar for years to most workers at WRE, is that of Ellen Maude (Nell) Dowd. Many people who still remember her with affection recall vaguely that she was sacked because she was a communist or had a communist relative. Her case achieved a good deal of publicity when she gave evidence in public before the Hope Royal Commission on Intelligence and Security in 1975. On that occasion she told a complicated story of harassment; harassment in which ASIO and the media seemed to figure equally. Insofar as she was a WRE employee, however, the story is clear enough. She was born in Adelaide in 1908 and worked as a clerk in various branches of Defence before coming to Salisbury in August 1947, where she worked first in the library and then as a teletype clerk. She had a bohemian and cheerful temperament which made her a successful nightclub proprietor later in the 1950s, and she never concealed her strong left-wing views. In March 1950 LRWE asked ASIO to do an 'urgent "Z" check on Miss Dowd',[33] because she was about to undertake a cryptography course in Melbourne. When the check was done, a 'trace' was revealed: a

Brigadier Sir Charles Spry, Director General of ASIO, after his promotion. (PA) step-brother who was a suspected member of the Communist Party. ASIO recommended her dismissal, but instead she was transferred away from classified work to another branch of Supply in Adelaide. This was very much against her will, and when she discovered the reason she went straight to the top by writing a spirited personal letter to ASIO's Director-General, Colonel C. F. Spry. Pointing out that she and her step-brother had been raised in different homes and did not see each other for months at a time, she reminded him that she had sworn on the Bible never to reveal anything she learnt at work. She spoke of her 'humiliation and anguish' and said that the support of her friends was not protecting her from 'the finger-pointing by others who, so far, have only heard the whisper of my disgrace and do not know the true facts'.[34] Spry was reportedly moved by this letter, and saw to it that all the security objections to her were withdrawn. On her own account she left the Public Service in 1952 and her later troubles, real or imaginary, had nothing to do with her work at WRE.

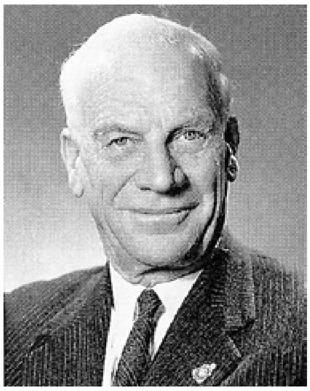
The story behind the incident which opened this chapter is more disturbing in its implications. Jackson's dismissal also resulted from the imposition of the 'guilt by association' test which was then being applied with grotesque zeal in McCarthyite America. The immediate cause was, in his opinion, the activities of a LRWE Security Officer who lived nearby in Salisbury North. This uninviting estate was at the time practically a Long Range Weapons enclave, subject to the petty jealousies of any small closed society. This may have been a factor; certainly an Assistant Security Officer (ASO), S. C. Neale, was asked to transfer voluntarily out of the Branch for compromising the Jackson case by revealing the official interest in Jackson, thereby potentially embarrassing ASIO and the government.

In 1936, many years before in England, Jackson had had a short workplace friendship with a union official, Joe Goss, who told him that he was Secretary of the Young Communist League. Jackson thought little of it. He had no interest in Communism himself, but he knew that many union officials, like many scientists and intellectuals, were Communists in the England of the 1930s. To be so was practically respectable.

In December 1950 Jackson was astonished to bump into Goss in Hindley Street, Adelaide. He marvelled at this coincidence to his LRWE workmates (as some of them remembered later), and Goss visited his home twice. On the second occasion, in January 1951, Goss got into a political argument with the wife of another visitor, and in the heat of discussion made his communist beliefs known. Jackson then told Goss that they ought not to continue their association. They did not meet again and in June Goss returned to England, where his wife had fallen ill.

Early the following year Jackson received a letter from Goss in England saying his wife had died and he was returning to Adelaide with his children in April. Jackson and his wife decided it would be charitable at least to meet Goss at Port Adelaide and perhaps look after his children for a few days. They did go to the Port (Jackson's wife was given a lift there by ASO Neale, to whom she described the situation). In fact Goss had several well-wishers to greet him, so the Jacksons parted from him at the docks. They saw him only once more, almost a year later in Easter 1953, when they responded to an invitation to visit him in his new home. That was the full extent of the contact between them when ASIO reported to Supply that Jackson was a communist sympathiser.[35]

Jackson's resentment at his sacking was at first acute, especially as he had no right of appeal and no one to champion him. He approached K. C. Wilson, MP, MHR for Sturt, who took it up with the Minister, Howard Beale. Beale was briefed on the case by Director-General Spry on 10 March 1954 in terms which may have been less than adequate.[36] Beale then confirmed the dismissal. For some weeks things were unpleasant for Jackson: his children came crying home from school where they had been taunted with 'your father's a Communist!' and his wife was asked to resign her membership of the Red Cross. But in the longer term there were no repercussions. His life was not blighted; quite the contrary. He had no difficulty in finding another job. He went to Chrysler's Aircraft Division, which at that time was working on the Jindivik target plane. He was quite frank about his reason for leaving LRWE but he found the management could not care less; indeed, with his specialist knowledge he was given a warm reception. Gradually the mental scars healed and the sense of grievance dissolved. He left Salisbury and ran a successful boarding house by the sea for some years, then he bought and sold property and eventually retired with comfortable means. By some odd stroke he continued to have no trouble at all in getting a pass to visit Woomera village where a relative lived.



Keith Cameron Wilson, Liberal MP. (PA)

What of the charge that the blanket of security over joint project work hindered the democratic process? Certainly secrecy did provide the government of the day with a convenient means of sidestepping awkward questions from the Opposition on defence expenditure. On one occasion in 1952 when Mr Drummond MP brought this subject up in the House of Representatives, Prime Minister Menzies quashed it by mentioning his 'simple rule':

> If there is any doubt whether information on work of that kind might help a potential enemy, no such information should be disclosed. It is better that we should go without a little news than that a possible enemy should have too much news.[37]

This last proposition governed all official thinking, and it served to keep many aspects of the project, particularly the precise details of the intergovernmental agreements over finance, out of the arena of public and parliamentary debate for many years. To that extent democracy was subverted, but it was a rather minor sort of subversion. We find no evidence that security covered up any outrageous abuse of power, or any really serious malfeasances of government.

The effects of tight control on the professional lives of scientists employed by the joint project are even harder to pinpoint. Certainly in the early years of the project it was not uncommon for scientists in academia, industry or the CSIRO to deplore any security restraints being placed on their researches. While he was chairman of CSIR Sir David Rivett never missed an opportunity to argue that scientific information must flow unimpeded by the state to be science at all. But this is an extreme and idealistic position, for no country in the world freely exchanges all its scientific and technical information. The flow is restricted for commercial no less than national security reasons, and yet it would be hard to prove that commercial secrecy has seriously impeded the development of, say, computer technology.

What of the delays in publication caused by the need to obtain a security clearance first? It is commonplace for a new discovery to be made simultaneously in several centres working independently on the same problem, and sometimes it has been acutely important to an individual scientist or team to get into print first. However, little defence science of the kind done in Australia is likely to produce such a crisis. While a device or a set of performance figures might well be put under wraps for some years, this is less likely to be the case with a new technique or a new theory. Those who chafed especially under the obligation to submit every paper for clearance presumably left when they could for more congenial posts, though no one can recall a departure from Salisbury for that reason. It should be said that the Department of Defence has never been slow to patent devices and techniques originating within the Establishment. One example was the 'fish-eye' 183 degree camera lens developed under the Jindivik target aircraft program, which proved a considerable success in the market place.

Notes and Sources

1. Some censored papers on this case were released by ASIO under the Archives Act in 1986. A note of a telephone call between Security staff on the day of the dismissal confirms the deliberate haste: '[Jackson] will only be given a couple of hours notice. I instructed full surveillance for today and tonight and afterwards as thought necessary.' AA A6119/XR1 Item [177],
2. Letter dated 21 February 1947 to Defence Secretary Sir Frederick Shedden. Shedden Papers box 1390.
3. 'Wider defence works', *Sydney Morning Herald*, 25 September 1947.
4. Quoted from the LRWBA Security Plan of 1949. Security Branch file 195.
5. Report dated 28 September 1949 to the Security Officer LRWE. Security Branch file 24. The Department of Defence did draw the line at a proposal from Supply that part of the Salisbury base should be turned into a migrant camp and up to 3000 Displaced Persons housed there.
6. Reminiscence of Mason Clark in an interview of 12 November 1984.
7. A comment of former Woomera resident Peg Bell, in an interview of 3 October 1983. Some officers within Security itself thought these regulations unnecessary and 'puerile'. Alan Flannery, later Range Security Officer at Maralinga, recalled in March 1984: 'I was vehement in my protests to successive heads of Security at Woomera about this absurd regulation—but to no avail.' Flannery further pointed out that the village remained closed after the late 1950s thanks to an administrative decision, which went against advice from Security.
8. Reminiscence of John Maddern, Assistant Inquiry Officer 1949-54 and Security O.I.C. Salisbury 1954-63, in an interview of 8 December 1983.

9. Their suspicions were well founded, for a set of proposals dated 7 October 1947 sent from to LRWO(A) headquarters in Melbourne mentioned that 'undercover Agents will be employed . . . to keep Scientists and Technicians employed under constant surveillance.' AA AP589/2 box 6 file S I 493/2.
10. Report dated 20 May 1949 to OIC CIS detachment Woomera. Security Branch file 220.
11. Maddern interview.
12. Anecdote of E. H. Medlin, now of the Physics Department, University of Adelaide, in an interview of 7 November 1983.
13. Mr Cameron (Lib, SA) as reported in 'MP warns about rocket spy risk', Sydney Morning Herald, 8 March 1947.
14. 'Range security' (editorial), Advertiser, 16 June 1948. When CSIR's Division of Aeronautics was transferred to Supply one person failed the security check and another resigned rather than be moved. In July 1949 Dedman reported to Chifley that he had ordered security checks on all the high-ranking CSIR staff: Rivett himself, Drs Richardson, White, Clunies-Ross, and all their personal assistants. Shedden Papers box 1795.
15. Letter dated 1 October 1947 from Dedman to Minister for Munitions J. I. Armstrong.
16. Quoted from a Department of State office memorandum dated 5 January 1950 (misdated to 1949) reviewing the history of the embargo. US National Archives file 847.20/1-549. It is known from the Shedden Papers that a Major General J. H. Burns of the Pentagon was appointed 'Special Consultant to the Secretary of Defense on Politico-Military Affairs' late in 1949, perhaps to oversee Australia's progress in upgrading its security provisions. Shedden wrote to Burns on 23 November 1949 denying rumours that had appeared in N*ewsweek* earlier that month that leakages had occurred from the Department of Supply headquarters at 339 Swanston St. Melbourne and had been followed by a raid by Security. It had no substance: the story had been worked up by an imaginative journalist from an actual incident of a routine Security check of the building before work began one morning.
17. Report to Secretary Department of Defence dated March 1949. The Secretary in turn reported in a note on progress for June 1949 to Gordon Gray, Secretary of the Army at the Pentagon, that 'a tentative identification of the principal spy master of the network has been made, and his present activities are under active investigation.' In fact as early as February 1948 Chifley was informed that a British paper had leaked from the Department of External Affairs to 'a foreign power'. Shedden Papers box 1677.
18. Telegram dated 6 December 1948. US Department of State file 847.20.
19. Letter dated 1 July 1949 to Chifley. Shedden Papers box 1795.
20. Memorandum of conversation dated 20 April 1949, preserved in the Dean Acheson Papers held at the Henry S. Truman Library of the US National Archives and Records Service. Shedden was only invited to Washington at the request of the British government, which was becoming increasingly concerned about the effect of the embargo. In fact Chifley requested permission to state in Parliament that the US had initiated the request for the Shedden visit, but Acheson declined to permit this. Shedden himself thought his Washington visit was premature. The US Ambassador's acid comments on the Security Plan are contained in a long report dated 7 October 1949 from the Embassy in Canberra to the Secretary of State. US Department of State file 847.20/10-748.
21. Report, 'Establishment of new Australian security service', dated 24 March 1949 from Chargé d'Affaires Foster in Canberra to the Secretary of State, Washington. US Department of State file 847.20/10-748.
22. Quoted from a full and critical analysis dated 8 July 1949 of Jurika's report by Chargé d'Affaires Andrew B. Foster to US Naval Attaché J. Harold Shullaw in Melbourne. US Department of State file 847.20/7-849. Strangely, Evetts had the quite false impression that Jurika was passing very negative views to Washington and that he must be 'a past master at double-crossing'. Letter dated 29 August 1949 to Shedden. Shedden Papers box 1795.
23. Quoted from a report dated 8 March 1949 from an Assistant Inquiry Officer to the Security Officer LRWE. Security Branch file S/83/49.
24. Anecdote of Alan Sharpe, at the time of his retirement Deputy Chief Defence Scientist, in an interview of 7 December 1983.
25. Cable dated 15 March 1949 forwarded by J. J. Dedman to Shedden. Shedden Papers box 1677.
26. Minutes of Board of Administration meeting 42 of 10 November 1949.
27. 'Dept, realizes some danger this action will be interpreted by leaders opposition as prompted by change in govt. Same conclusion cld. conceivably be drawn by new govt. In either case such interpretation our action undesirable and embarrassing US-Austral relationship . . .' Cable dated 28 December 1949 from Acheson to American Embassy, Canberra. US Department of State file 848.20/10-2149. Shedden had gathered earlier in the year that the Americans were delaying until after the election on the supposition that the Labor government would fall. Nevertheless, Secretary of Defense Johnson approved the relaxation just before the election although the news was not conveyed to the Canberra embassy until two weeks after it.

28. ‘Denial on rocket information’, *Advertiser*, 5 October 1951. The classifications had been expanded to include Secret and Top Secret in March 1950, but the flow was impeded until 1953.
29. Notes dated 7 June 1954; letter dated 19 July 1954 from Director-General ASIO to F. O’Connor, Secretary, Department of Supply. AA A6122/XR1 Item [188].
30. Maddern interview.
31. This case was given wide media coverage in Britain and Australia at the time.
32. Although ASIO was not prepared to release details of its operations in the Skripov case to the author, it offered this judgment in a letter of 3 July 1985.
33. Memo dated 16 March 1950 from Security Officer LRWE to OIC ‘D’ Branch. AA A6119/XR1 Item [176].
34. Letter dated 17 August 1950 to Colonel Spry. AA A6119/XR1 Item [176].
35. This account is based on those parts of ASIO’s case file released to the author under the Archives Act and on interviews with Jackson. There are some small inconsistencies, both between the two written statements Jackson made at the time (17 and 26 February 1954) and, not surprisingly, between the statements and the interviews thirty years later; but the released ASIO documents support the interpretation that he was the victim of a particularly vacuous ‘guilt by association’ charge. The evidence against him consists of these allegations: that in February 1953 he had ‘a wide and intimate knowledge of both the Young Communist League and the Communist Party in London’; that he was friendly with a man ‘who as an importer [of dress accessories] would have connections with overseas shipping’; that he had painted some anti-Fascist slogans in London during the Spanish Civil War; that he had made various admiring comments about Goss. ASIO did not surrender its interest quickly. In April 1954, two months after his dismissal, the Acting Regional Director SA reported darkly to Headquarters that Jackson ‘has become interested in the International Film Society and attended a recent session. He intimated that he intends to continue to give it his patronage.’ AA A6119/XR1 Item [177],
36. It is unclear (for the report of the briefing is partly censored) whether Beale was informed of one piece of evidence critical to Jackson’s innocence. Immediately after he had discovered Goss was still a communist, Jackson had warned a LRWE colleague, David Miller, that as Goss was in his (Miller’s) Gilbert & Sullivan club, he should be cautious about the association. This was independently confirmed by Miller. Letter dated 15 February 1954 from PO Optical Group to Chief Superintendent Bareford. AA A6119/XR1 Item [177],
37. *Hansard*, House of Representatives, 1 October 1952.

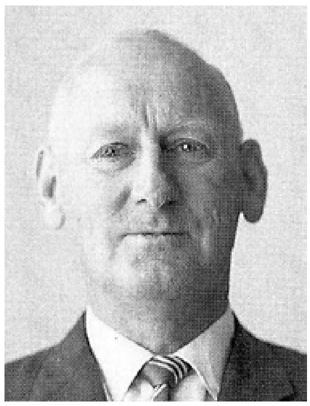
8 Woomera rises, 1947-54

PHYSICAL SETTING

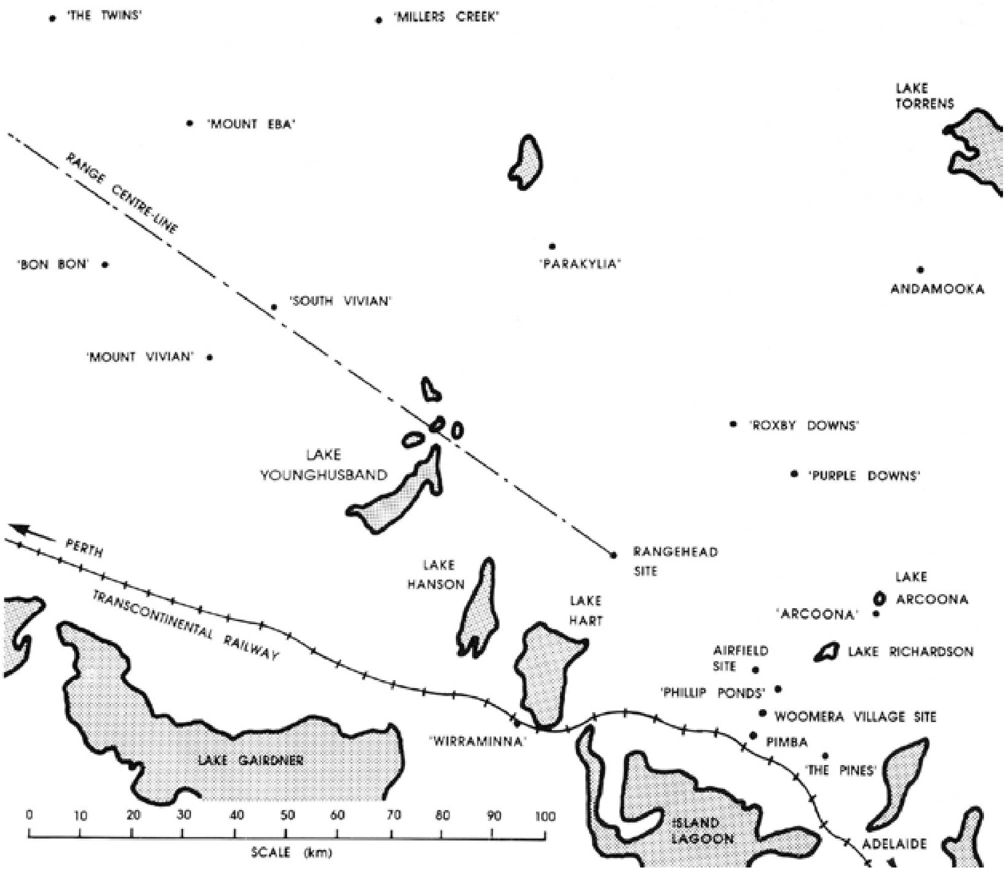
From a purely technical perspective the site selected for Woomera could hardly have been improved if some godlike planetary architect had deliberately moulded this part of his creation into a rocket range. The climate and the clarity of the atmosphere were superb, so that the techniques of optical tracking were able to reach the pinnacle of perfection. The great overland length of the Range could easily accommodate any existing requirement; and should it be needed later (it never was, in fact) a sea extension some thousands of kilometres long could be added over the Indian Ocean with the Cocos and Christmas Islands conveniently positioned to support observation posts. The flatness of the terrain, desert vegetation and lack of surface water made recovery fairly easy, and only 1 per cent of the rounds searched for were not recovered. Any danger to people or risk of damaging property could practically be discounted. What eventually emerged as the chief handicap of Woomera as a range for orbital launchings—that satellites could not be launched over the populated eastern coast, which meant foregoing the benefits from the catapult effect of the earth's rotation—was well beyond the ambitions of the time.

The political circumstances were no less advantageous. Australia, as host to the Range, had no peer in its internal stability and the predictability of its foreign relations. Anglophile to the point of idolatry, it identified totally with the defence goals of the British Commonwealth and America, regarding most of its Asian neighbours with xenophobic mistrust and incomprehension. Probably of all countries friendly to the West it was the one least likely to forge inconvenient alliances or to suffer internal convulsions permitting secret equipment to fall into the hands of insurgents. Australia was, in a word, reliable. It was also very secure. Not only was the whole country itself distant from the main axes of population and power, but the Range was situated in a vast harsh and unpeopled region where no stranger could pass undetected. In those days before spy satellites, prying eyes could be kept at bay by such simple expedients as making sure that planes on the commercial TAA Adelaide-Darwin flight kept their curtains—which had been specially manufactured to Security specifications—firmly drawn during the Woomera fuel stop.

Unfortunately these technical and political advantages exacted a high price. The logistical problems of setting up a Range and supporting community at Woomera were enough to make the most skilled administrator blench: it was as though the authorities had plumped themselves down and decreed, 'let a town arise!' Australians had, to be sure, some experience in establishing mining towns from scratch in inhospitable country, but they had never had to do so with such urgency or for such a specialised purpose. Communications were far from good. No airfield existed anywhere near the site and the closest point on the east-west railway was Pimba: just a handful of houses, a rest room for train crews and a tiny school whose sole teacher, George Pearce, lived in a one room shack opposite the railway line. An unsealed track was the only route back to the small town of Port Augusta and the south. Within a radius of a thousand kilometres lay only one city capable of meeting the myriad needs of the project, and the Adelaide of the day was far from being a highly industrialised metropolis. The sole outback industry was wool production by vast stations running a few sheep to the square kilometre. No permanent surface water and no artesian water supply existed and, apart from meat from the stations, every gram of food would have to be brought in. There was no electricity, no telephone lines, no decent roads, no drainage, no shelter of any kind except for a stockman's derelict cottage. Every kind of building material—cement, corrugated iron, piping, glass, cable, electric switchgear—was already needed in a country



Alan Bouch, the resident Project Officer who supervised the building of Woomera.



The rangehead and support town (later named 'Woomera') were originally to be near Mt Eba, but in early 1947 new sites were chosen closer to Adelaide and the transcontinental railway.

which had just emerged from a global war, and what there was had been earmarked for the housing industry. Over the first critical years the task of solving these daunting problems fell to one man above others: Alan Bouch, the big jovial Project Officer of the Department of Works and Housing which established itself early in 1949 at Woomera West (a site which remained active for the next twenty years) and at Koolymilka near the rangehead. Roads, water, power, buildings: all these had to flow in an unending stream from 'Works and Jerks'. The shortages in the face of the constant pressure to speed up the work made extraordinary demands on the ingenuity and patience of Bouch, whose talents were so admired by his men that one later said 'he should have had the VC given to him!'[1] His only comfort was that the flow of cash was practically unlimited and the priority absolute.

By the time early in March 1947 when the 'Evetts eleven' had all arrived in Australia, the decision had already been taken in principle to draw back the rangehead from Mt Eba to the Pimba-Phillip Ponds area. This extended the length of the Range somewhat, and some temporary lakes in the new region offered an immediate supply of potable water. Most importantly, though, it shortened the lines of communication. The new choice was some 144 kilometres closer to an established settlement and much closer to the transcontinental railway. The spur line would need to run only 14 kilometres from Pimba, instead of 130 kilometres from Kingoonya. The plateau site also offered an area for the runways and rangehead unimpeded by vegetation. Of the two possible locations for the village—the first, in a wooded depression near The Pines homestead; the second, out on the plateau on the track already running from Port Augusta to Mt Eba—the latter, at the southern end of the Phillip Ponds depression, was seen as having a number of distinct advantages, and was the one chosen.[2]

Aesthetically the new site had little to recommend it, for it was far more barren and uninviting than the landscape around Mt Eba. In pressing the advantages of the latter, the South Australian Director of Mines urged the point that the Arcoona Plateau is 'a bleak and cheerless region without vegetation and of very poor soil, and would be very depressing for permanent living whereas a site a little further out . . . has much more attractive features'.[3] To this Wynne-Williams, consultant engineer to the organisation, replied that 'we cannot, unfortunately, choose a site because it would be pleasant to live in. A covering of vegetation would rule out a site . . . It is to be hoped that the Director of Mines' statement that the soil is very poor will be available as evidence when the price of the land is being considered'.[4] The absence of many natural features did have the advantage that the plan of both township and Range could be drawn full scale on the ground as though on a giant map. The only limiting condition was that the town should be a normal country town, with as few restrictions on the populace as possible and certainly with no out of bounds areas within its perimeter. So the town was positioned between the airfield and railway with the rangehead some 32 kilometres distant: sufficiently remote to present no hazards to the townsfolk.

RAF officer N. H. Fresson, one of the Evetts eleven.

A small survey party comprising N. H. Fresson (one of the 'Evetts eleven' based in Melbourne), George Pither (RAAF Liaison Officer to the LRWO) and Bill Dale took a jeep up to fix the site of the first airstrip and thus the location of the rangehead. The going was rough, but eventually they came to some promisingly flat terrain north of Pimba railway station. Dale, the driver, spotted a black snake slithering through a clearing in the thorn bush. He made for it and pinned it under his front wheel. Then everyone got out and after a little exploration decided that here indeed was the spot. The moment seemed vaguely symbolic: the earthy red desert stretching to the horizon in the heavy silence and the heat; the venomous snake dying under the wheel of the jeep; a weapons Range about to be born.

On 4 July 1947, as soon as two temporary 4500-metre landing strips had been graded, members of the Long Range Weapons Board of Administration headed by Evetts lost no time in making a two day inspection of the selected area using two Dakotas. It was in the press report of this visit that the public first heard the name 'Woomera'.[5] An official search had been on for some time for a good name, since the only other proposal had been 'Red Sands'—a lacklustre outback version of the famous White Sands range in New Mexico. At a Board of Administration meeting in April 1947, 'the opinion [was] expressed that if a suitable aboriginal name was available it should be favoured', and the Board members were asked to give the matter their consideration.[6] Pither and Fresson thereupon obtained a glossary of Aboriginal names and went through it until they hit on the term which now sounds so inevitably right. A *woomera* is a spear thrower in a language of eastern Australia, although ironically the Aborigines of the western desert culture, which includes the Woomera area, had a different word: for them the device is a *miru*. More exactly, it is a flat slice of mulga wood a little under a metre long. A hardwood peg set at an acute angle is glued or bound with kangaroo sinew into one end. The peg slots into a hollow in the butt of a spear. In taking aim both woomera and spear are held in one hand and parallel along the line of sight. The leverage almost doubles the force of the spear throw and a skilled hunter can pierce a bird on the wing.

Pither suggested the name to Air Marshal Wackett, who was his chief and the Air Force representative on the Board, and at the next meeting on 24 April the name of Woomera was formally adopted.[7] Later in a short editorial the Adelaide A*dvertiser* drew a rather clever moral by pointing out that a *woomera* is an implement of varied purposes: it can be used as a spear thrower, as a shallow dish, or as an adze, a gouge or a chisel—in other words as an item of aggression or of daily utility.[8] Going one better, Dr Duguid suggested that since the consequences were likely to rebound on everyone's heads, a better name would surely have been Boomerang.[9] At first the intention was that Woomera should be the name only of the town, not the Range as well, but this distinction quickly disappeared. On the occasions when the people living there need to distinguish the town from the Range, they call it 'the village', and we shall follow this usage.

A *woomera*.

BLACK BANNING WOOMERA, 1947–48

Considering the rigours of the site—its aridity, its remoteness, the lack of entertainment and basic comforts—Woomera was built with remarkably few labour disputes. One early expression of discontent came from an unexpected quarter: some of the 420 RAAF men of the No. 2 Airfield Construction Squadron (2ACS). In October 1947 bitter complaints were voiced that they were living four to a tent, eating poor and boring food, working on Saturdays, and worst of all that their beer ration of three bottles a week was not being met. Thirty-two men a week were said to be seeking a discharge.[10] The officer in command was quick to retort that he himself was living under the same conditions and there was nothing really to grouse about; and perhaps he was right, for no more mutinous rumblings were heard.

Altogether more idealistic motives lay behind the first hint of union concern over constructing the Range. On 14 March 1947 the Adelaide United Trades and Labour Council decided to recommend to the ACTU that a ban be placed on 'the manufacture of the rocket weapon' in South Australia. The motive was a purely pacifist one: the Council resolved that 'the way to world peace lay in total disarmament by all nations, including the manufacture of the atomic bomb'.[11] Further, the ACTU was to be asked to recommend to the world federation of trade unions that the ban be actively supported in every country.

Here the matter lay quiescent for nearly two months. Then it flared up again on 9 May 1947, this time in Melbourne where the Building Trades' Federation (BTF), a loose group of eight building industry unions which had only been founded some eighteen months earlier, decided to recommend to its affiliates that all Range construction work should be black banned. The secretary of the Federation, Donald Thomson, explained that there were two good reasons why the ban should be imposed: first, it was senseless for Australia to engage in weapons research that would make it a future military target; and second, the money could much better be spent on housing, social services and peacetime plans for developing the country. He also touched lightly on the Aboriginal question.

The BTF's motives were at once roundly impugned on all sides. As leader of the Opposition Robert Menzies was spoiling for a fight, and he took no time in urging the government to show its mettle. One would have to be stupidly naive, he said, to believe that the BTF, which all the world knew was riddled with Communists, was actually moved by any pacifist impulse. The truth was, 'because they are pro-Russian and anti-British, they want rocket experiments to be conducted by the Russians and not by ourselves'. So what was the Labor government going to do? Was it, demanded Menzies, really going to let its policy on 'a vital matter of Empire defence' be dictated by a few unionists whose allegiance to the country was more than questionable? Was it going to be pusillanimous or was it going to, 'call Mr Thomson's bluff and use its authority to see that the Range is built'?[12] All decent citizens were keen to see just how lily-livered the government might prove to be.

This was Menzies at his most bellicose; but as so often he had tapped the mood of the many Australians who were keen to see the whip cracked over unionist, and preferably communist, heads. The ban suggestion also fell victim to some atrocious timing. It had coincided with the May Day celebrations in Moscow where the latest weaponry had as usual been on display. Sardonic remarks naturally followed, speculating on what nasty fate would have befallen any Russian workers suicidal enough to ban the construction of weapons in the cause of world peace.

OLD BLACK JOE

The central committee of the Australian Communist Party declares that its opposition to construction of the rocket range is based solely on the danger of rockets to the Central Australian tribes.

This is how cartoonist Frith of the *Sydney Morning Herald* interpreted the early communist attitude. (SMH)

How did Australian labour and those claiming to speak for it respond to the call for a black ban? Because of the number of organisations, many autonomous in practice if not in principle, the matter was complex; but generally speaking the trade union response can only be described as icy. Even inside the BTF itself there was no single agreed philosophy. It is true that although the Communists had a politically insignificant membership—not more than about 23 000 in 1945, a figure that shrank continuously through the 1950s[13]—they did wield influence in some groups like the BTF out of all proportion to their numbers. But within each union of the Federation there were great differences in the degree of influence, and in this case it proved to be a very unreliable guide to the stance taken. Only in one union, the Building Workers' Industrial Union (BWIU) which had at that time a membership of 15 000, was there a solidly communist officialdom. Three other unions, the Builders' Labourers, the Plumbers', and the Tile-layers', were avowedly anti-communist, and these had a combined membership of 15 500. The remaining three smaller BTF unions—the Painters', Plasterers', and Road Transport Workers'—had some influential Communists in their ranks, but in this matter they reacted very variously. Only the federal council of the Painters' Union immediately endorsed the ban. At once the federal secretary of the Builders' Labourers countered with the brisk statement that members of *his* union were available for work anywhere that wages and conditions were good. So much was predictable. More exceptionally, the large and communist-dominated BWIU introduced a new note by putting aside any pacifist and economic arguments for the ban. The BWIU's line was that 'our national minority'—the Aborigines—should not be caused to suffer' by reason of defence plans: phrasing which seemed, implicitly at least, to be recognising those plans as legitimate.[14] The attempt to bring the Aborigines to centre stage was strategically a weak move, since that cause had lost support. The division of opinion was at once spotted, and the cynical interpretation was that the Communists were casting around for an issue and were preparing to run for cover.

Such a view seemed to be justified when, on 13 May, the central committee of the Communist Party issued the following statement:

> The leading party committees have never, at any time, even discussed, let alone advocated, a policy of preventing Australian experiments with modem technical military equipment . . . we believe Australia should possess all weapons necessary to the defence of this country. We believe that a 'black' ban on the range would be mistaken policy . . . the matter should be resolved by arousing public opinion . . . Communists fought for Australia in the war just concluded; they will do so again if ever she needs defending.[15]

Even the most charitably disposed could not but find this a surprising volte-face, and Mr Fadden, leader of the Country Party, acidly described it as a 'another retreat from Moscow'. It is hardly conceivable that the Communists did not know about and had not given their tacit support to the BTF; and in any case this new stance hardly squared with earlier less circumspect assertions. Alf Watt, South Australian secretary of the Party and also a member of its central committee, had not minced his words over what he saw as a classic guns before butter policy. 'Armaments are dead production', he had argued in a pamphlet. 'The huge armament programme that will press so heavily on Australian standards of living, will not defend Australia.' With a different policy, that of peaceful co-existence with the Soviet Union, we could have 'experiments into pilotless cargo carrying aircraft, instead of into pilotless juggernauts'.[16] The later changes of heart struck many as yet more evidence of the fragmentation and slack discipline of the extreme Left. The general perception was that, having backed a horse that was just not going to run, the Communists were eager to withdraw with all the dignity they could muster, which was not very much.

A. W. Fadden, Country Party leader in 1947. (PA)

In South Australia, where the issue was most immediate and the call for a ban had originated, the response was hardly less muted than elsewhere. The local branch of the Building Trades' Federation, whose secretary was J. L. Cavanagh, trod more cautiously and let it be known on 20 May 1947 that the ban recommendation would be put to each of the affiliated unions and a majority vote would determine Federation policy in that state. The result was clear cut: on 29 July 1947 it was announced that only two of the member unions, the Builders' Labourers' and the Plasterers' Society, had supported it and the ban was therefore rejected.[17] In the meantime, with what must have been a singular lack of optimism, the two delegates from the Trades and Labour Council had taken the ban recommendation it had carried months earlier to the executive meeting of the ACTU in Sydney on 2 June 1947. The ACTU's president, P. J. Cleary, had already taken exception in public to the BTF's attempts to speak for all unionists, and inevitably the full executive rejected it, saying that while an intense armaments race continued Australia had no option but to prepare its defence against the new weaponry.

The response of labour organisations outside the BTF was even more unequivocal. Broadly, the view of both centre and right wing unionists was that projects involving the security of Australia itself were simply off limits for strike action, especially for nebulous reasons of political principle. Pragmatism was the order of the day. The New South Wales Trades and Labour Council, for example, weighed in with a pugilistic metaphor of its own, 'it is ridiculous to put away your gloves if the other fellow is still wearing his'. For just one section of the world's workers to ban rocket tests would be absurd, said its secretary, R. A. King; and he too deplored the BTF's attempt to run its own line on such a sensitive issue. The biggest union in the country, the Australian Workers' Union, would not hear of a ban and its general secretary, T. Dougherty, roundly denounced such talk as sabotage. 'Nobody should dare to presume against a Government, whether Labour or anti-Labour, when it had decided on a line of defence policy',[18] he proclaimed—a line so very patriotic that it precipitated some sour remarks from the president of the Sheet-metal Workers' Union about the 'new jingoism of right-wing trade union officials'.[19]

In short, this was a case where one official of one federation of unions released an inflammatory statement which certainly did not find favour with many of the rank and file of those unions; which was supported by only one union within the federation and by none outside it; and which was generally rejected and condemned by spokesmen reaching right across the political spectrum. This being so, the government's almost hysterical reaction can only be viewed as more symptomatic of the mood of the times than as a reasoned appraisal of the threat to Australia's security. Newspapers vied with each other in producing alarmist editorials; one typical warning was that 'cherished scientific projects are menaced by a black ban . . . such defence work should not depend on the whim of any union which seeks to arrogate to itself the functions and responsibilities of government'.[20] To be sure, some managed to keep their heads. The Minister for Defence, John Dedman, refused to be stampeded and his remarks throughout were notably temperate despite considerable provocation. Insisting that the risk to the Range program was still only a potential one, he coolly rejected calls to bring back Army and Air Force units to form construction crews. He said that no doubt they could build airstrips, but he did not believe they could tackle the more complex engineering tasks. If individual workers or unions refused to take part in the Range construction then non-unionised labour would be hired. Every individual had the right to an opinion about the Range; he believed such opposition was misguided, but the government should not suppress opinion about it. In the prevailing highly charged atmosphere, with calls for a public inquiry into 'Communist traitors', it was good to hear someone say so.

Attorney General Dr H. V. Evatt. (PA)

Unfortunately his was not the point of view prevailing in Canberra, which had become infected with the virus of antipodean McCarthyism. The news broke on 29 May that the federal government was on the point of presenting a Bill to Parliament in the current session to impose severe penalties—a fine of up to £5000 and/or a year's imprisonment—on anyone disrupting top priority defence projects by sabotage or boycott. The government moved quickly and it fell to Dr H. V. Evatt as Attorney General to introduce the Bill on 3 June—somewhat ironically so, since he himself was later to be smeared as a fellow traveller by the DLP during the Petrov affair.[21] The Approved Defence Projects Protection Act was passed by the House of Representatives without amendment at 3.30 a.m. on the morning of 6 June; an occasion when, according to Mrs Blackburn, too many Members were asleep on the benches to constitute a quorum. As it happens, the Act has never been invoked; but potentially at least it remains an extremely oppressive piece of legislation. Its most disturbing clause is the wide ranging 4(iii), which allows the punishment of anyone who 'by speech or writing advocates or encourages the prevention, hindrance or obstruction of the carrying out of an approved defence project'. (A few days later, by a Special Gazette, Woomera was formally declared to be such a project.) Evatt, in introducing the Bill in the House of Representatives, tried to introduce a distinction between a strike and a boycott. A strike, he said, is an action by workers to improve industrial conditions; a boycott is the 'misuse' of industrial power for political or international purposes. Only the latter was to be outlawed.

Practically no one protested against this remarkable piece of verbal legerdemain, not even when Evatt made the firm point that the clause applied just as much to speakers in traditional havens of free speech like the Domain as elsewhere; and that if a newspaper gave its support to a boycott then 'it would be a much more serious offence than an attempt by some obscure person to start one'.[22] The Act was, of course, a transparently anti-communist measure; an adumbration of Menzies' Communist Party Dissolution Act of three years later. The Communists themselves recognised the Act for what it was and denounced both it and Evatt in their paper Tribune:

> One might consider it wrong for the Government to spend ten times more on armaments today than it spent in pre-war years, but if all or any of the works on which the money is being spent have been declared 'approved defence projects' one runs the risk of a twelve months' gaol sentence if any of Dr Evatt's supersnoopers happen to overhear . . . When the full implications of Dr Evatt's hurried legislation become clear to Australian democrats there is sure to be a tremendous storm of protest.[23]

But the *Tribune* was wrong. There was no storm, and the Bill passed into law with little parliamentary debate. The only aspect of it which exercised the Opposition was that perhaps the prescribed penalties were not severe enough. Outside Parliament a few squalls blew up. A copy of the Bill suffered the indignity of being torn in half in the pulpit of the Melbourne Unitarian church[24] and the indefatigable Charles Duguid said darkly that 'to save the children of today in every country from such diabolical cruelties concocted in cold blood gaol will be suffered gladly by all parents who put their faith in common sense and the United Nations'.[25] But Dr Duguid was blessed with no more of a prophetic gift than the Communists. The Rocket Range Protest Committee made little headway, and no one went to gaol, gladly or otherwise. The main reason was that those responsible for drafting the Bill had cleverly defused the pacifists and conscientious objectors by including a vague 'without reasonable cause or excuse' clause, and it emerged in debate that this had been specifically included to provide an escape hatch for those whose protests had no political overtones. There is no evidence that any person or group was actually cowed by the Act's Draconian provisions. The objection to it is that it was a gross example of overkill, for the BTF initiative was already dead from inanition.

Later on the next year, though, the government's will, as embodied in the new Act, was to be put to one brief test.

As the pace of construction increased in the first half of 1948 the unions realised a little belatedly that perhaps they ought to know more about the working conditions of their members, who by now numbered several hundred. So, towards the end of May, J. L. Cavanagh, the energetic state secretary of the BTF, sought a conference of all the branches of the Federation to consider the need for better wages and facilities at the Range. They arranged to meet on 16 July in Adelaide and to follow through with a visit to the site by all the delegates. On their return, they planned to talk to the Department of Works and Housing about better conditions: an isolation allowance of 30s a week, a minimum wage of £7-10s for a 40-hour week, two smokos a day and a first class weekend return trip to Adelaide after three months' work. But what began as a routine exercise in industrial negotiation soon blew up into a major confrontation.

Union official J. L. Cavanagh. (Adv)

At first arrangements for the visit went amicably enough. At the beginning of August Cavanagh asked permission to visit Woomera, and was informed by B. S. McCarthy, chief administrator of the LRWE, that up to twenty accredited and cleared union officials could make a visit on 25 August to talk to their members about wages and conditions. The Establishment would lay on the relatively luxurious Viking for the trip. Later, after further representations, it was agreed that in order to allow more time for meetings, three separate parties of unionists could make one visit each over three days. It all sounded very reasonable.

After that, however, matters deteriorated quickly. A conference on 6 August of all those unions with members at Woomera unexpectedly took a much more aggressive turn than hitherto. Tempers were particularly frayed by a report from one official. He had already been to Woomera, and while there he had been told that it was illegal to hold any meetings with his members. Furthermore, his every utterance had been recorded by a stenographer. Without pausing to confirm this report, the conference interpreted it to mean that a stop work meeting could be in breach of the new Defence Projects Protection Act. It thereupon decided to seek the repeal of this Act. This was an extremely unwise move. Obviously the Commonwealth would not yield before this sort of pressure, and the issue did not have enough support for the unionists to push forward with what must be a non-negotiable claim. Meanwhile, Cavanagh was upping the ante. By 8 August he was letting it be known that he was trying to organise a mass meeting of all 900 workers, so that their grievances, if any, could be thoroughly aired. The government had about a fortnight to mull over its response to what must have looked like an acute threat, and it let the bombshell fall on the Tuesday (24th) before the weekend visits were to begin.

In what would ordinarily have been a routine letter from the Chief Superintendent to Cavanagh giving formal permission for sixteen officials to visit Woomera, no fewer than five were refused the necessary permit including Cavanagh himself. (Four others did not at first return completed security forms.) No public reasons were given. In a letter from E. Hattam, Deputy Director of the Commonwealth Investigation Service, to the Security Officer at Salisbury there was said to be 'a strong security objection to the banned unionists', and the advice was that they 'should not be permitted to form part of the visiting party', though no explicit reason was given here either. Even the CIS file on Cavanagh only records the opinion that he 'is a member of the Left Wing Group of the Industrial Unions. He is at least a sympathiser or fellow traveller with the Communists and is probably a member'. Apparently this blend of common knowledge and unverified speculation was enough to produce the adverse report.[26]

Cavanagh instantly responded angrily with the reported threat that 'unless the position was rectified, the BTF would have no alternative but to withdraw labour from the range'.[27] The scene seemed set for a head-on confrontation which the BTF could only lose; both Dedman and the Acting Attorney-General Senator McKenna made it plain that the Commonwealth would brook no interference with its plans for the Range and would not hesitate, *in extremis*, to use the new Act.

The rejected men received little sympathy from the public or the media, which took the view that if they were not actually card-carrying Communists then they certainly had friends who were 'elements believed to be subversive of the community' (as the Acting Minister for Supply and Development, Mr Riordan, delicately phrased it) and therefore their loyalty to their country was under a cloud. Even the unionists themselves did not close ranks. Of the six unions whose officials did eventually get permits, four let their representatives go anyway, ignoring BTF protests. These officials visited Woomera on 27 August and held two meetings there with their members, each lasting over two hours. The industrial officer of the SA branch of the Australian Workers' Union, P. Galvin, said that he had addressed a meeting of about 400 employees. It appeared that the main discontent was the lack of showers. At the second meeting about 400 building workers were addressed by three other officials. The men adopted a resolution to press forward with a log of claims involving a 50 shillings a week locality allowance, free board and lodging and increased leave. Pointedly, and to general approval, they agreed that these claims should be pursued by conciliation. The four officials went out of their way to say that they had been given every facility for speaking to their members.

Early in September the BTF in South Australia was considering holding a meeting of Woomera employees at Pimba, outside the prohibited area, but this idea was quickly dropped when it found little favour with the labour disputes committee at Woomera itself. Cavanagh said that a member of a building trade union at the Range had told him by letter that at the public meeting the presence of security officers had intimidated employees from making complaints and that in reality the men were most unhappy with their lot. This lurid and unlikely story was immediately denied by the officials; no security officers had been in evidence, they said; and if the men had been afraid to voice complaints openly they had had plenty of opportunity to do so privately.[28] Meanwhile, another union, the Builders Labourers', which had so far considered itself bound by the BTF directive, now ordered its secretary (who had received a permit) to visit the Range as soon as possible. On 7 September the executive of the Trades and Labour Council decided that union officials visiting Woomera should comply with security regulations: as far as it was concerned, those banned would have to stay banned. Three more union officials paid a visit on the last weekend in September.

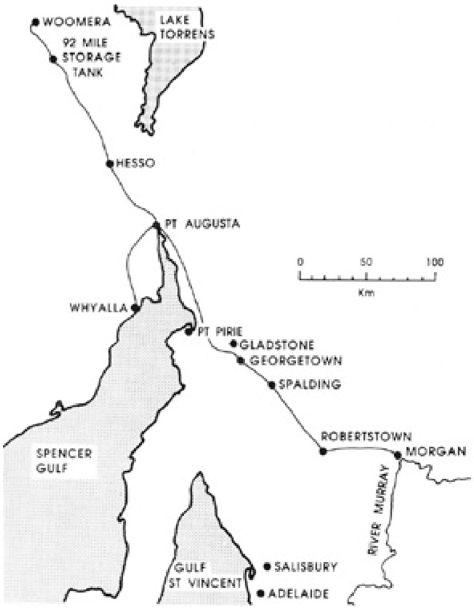
And with this the dispute faded away. After further negotiations on pay scales, during which the union claims were resisted by the Commonwealth, rates and conditions were set by a new Federal award. Weekly pay now ranged from £10-14s-7d for an unskilled labourer to £13-4s-8d for a tradesman, and different locality allowances depending on the work site of about another £2-16s were payable. It was good money for the time, and harmony once more prevailed. Even the BTF found the agreement tolerably pleasing, and no more talk was heard of strikes on the Range or mass meetings off it. These events, it turned out, were a prelude to a long period of industrial peace throughout the next two decades. It was not until the rundown and economy measures of the mid-1970s that the unions again took a particular interest in the Establishment, and even then the government's wish to reduce and redistribute the staff was achieved with very little friction.

BRINGING WATER TO WOOMERA

But we anticipate. For the architects of Woomera the first and most immediate problem was not union agitation but securing a reliable supply of water—the scarcest natural resource out on the Arcoona Plateau, where in summer the life expectancy of a man without it can be measured in hours. A telling anecdote from the time of the first Evetts mission gives an idea of what the planners were faced with. A public servant with a wide knowledge of pastoral conditions in South Australia's far north was summoned before Premier Playford and Evetts and sternly asked to give his evaluation of the water supply in the Pimba area. Rather overawed by the display of top brass and anxious to say the right thing, he replied loyally, 'It's not so bad!'—afterwards whispering to the Premier that what he had in mind was half a dozen sheep to the square kilometre, not a township of 1500 people.

Of course there could be no question of relying on surface water or rainfall. Only 190 millimetres of rain falls in the average year and in some years much less than that. Since the evaporation rate is around 2500 millimetres a year, it is small wonder that the lakes, creeks and swamps of the area are bone dry most of the time. Not always, though: over the last century freakish rainfalls have filled the lakebeds three times, most notably in the late 1940s. When the first construction gangs arrived on site Lakes Richardson and Arcoona together consisted of 1200 hectares of deep fresh water, although Arcoona's water was the more potable of the two. At first Phillip Ponds supplied water; water of good quality before hundreds of rabbits died in it that first summer. Then water was trucked in Chevrolet Blitz tankers from Arcoona, whose shore was easier to reach. But no time was lost laying a pipe from the closer Lake Richardson to the RAAF camp, and by the end of November 1947 a 320 kilolitre storage tank was delivering all that was required.[29]

No one deluded themselves that the brimming lakes were anything more than a useful gift which capricious nature would withdraw before long. When the Board of Administration sought advice in February 1947 about how long this bounty might last it was told approximately four years.[30] Here surely was an adequate breathing space which would see construction through its most urgent phase at least, and would allow the question of a permanent supply to be set aside for a while. Unfortunately the estimate given was far too optimistic. In May the South Australian Department of Mines warned the Board that fresh water might not be available for much more than a year;[31] and as the winter passed and the summer sun gathered strength this forecast proved to be much nearer the mark. At the end of the year the position deteriorated sharply. The summer was a hot one and as the lake water began to evaporate its salinity rapidly increased; it would not be drinkable for much longer. A plan to bring a demineralising machine up from Salisbury was dropped because the water was already too saline for the resins in the plant to cope with it. Instead the supply



Right: To give Woomera a permanent water supply, an existing pipeline from Morgan to the steel town of Whyalla was tapped at Port Augusta and a new 170-kilometre branch laid.

Far right: Welding a joint in the Port Augusta-Woomera pipeline during construction.

pipe had to be quickly extended an extra 13 kilometres to Lake Arcoona, which at that time still contained several metres of sweet water. Though this was evaporating just as quickly, its water contained less dissolved salt and so remained fresh to the end. The extra piping was obtained by recycling some from the cordite section of the old Explosives Factory.

For Woomera's permanent water supply no real alternative existed but to bring River Murray water to the site by tapping at Port Augusta the Morgan-Whyalla pipeline which had been built in 1944. Naturally the Board was anxious to avoid this heavy expense if possible, and it looked briefly at some alternatives. One grandiose scheme involved creating an artificial catchment by lining a big area of land—some 36 hectares—with two thousand tonnes of corrugated iron sheet, draining the gathered water into colossal storage tanks. More practically, though without much hope, the chances of a groundwater supply were also looked into. Test bores were dug at Phillip Ponds, Paradise Wells and Fred's Swamp, and one bore was taken down to 210 metres before being abandoned. In truth the quest was useless because the Plateau, unlike the original site at Kingoonya, lies on the extreme margin of the Great Artesian Basin.

Making a start on the inevitable pipeline was now crucial, considering that once construction started it would be at least a year before water started to flow. Fortunately most of the planning had been done earlier. The previous November Essington Lewis of the industrial giant BHP had promised Evetts that enough rolled steel sheet would be forthcoming at short notice if the position grew critical. Many years later Evetts gratefully recalled Lewis's eager assistance. The Board had also allocated more than half a million pounds for the task of laying a spur pipeline 170 kilometres long and building a pumping station at Hesso. Most important of all, and despite political protests that the pipe would 'snake past the homes of Iron Knob schoolchildren whose drinking water is rationed,'[32] the South Australian government had agreed that 1.3 megalitres a day for Woomera could be diverted from the main pipeline, as long as 78 kilolitres a day was made available at cost price to graziers en route. (About seventeen such taps were installed at first.) But would something more than a megalitre a day be enough for the needs of the village and Range together?

BHP steel magnate Essington Lewis.

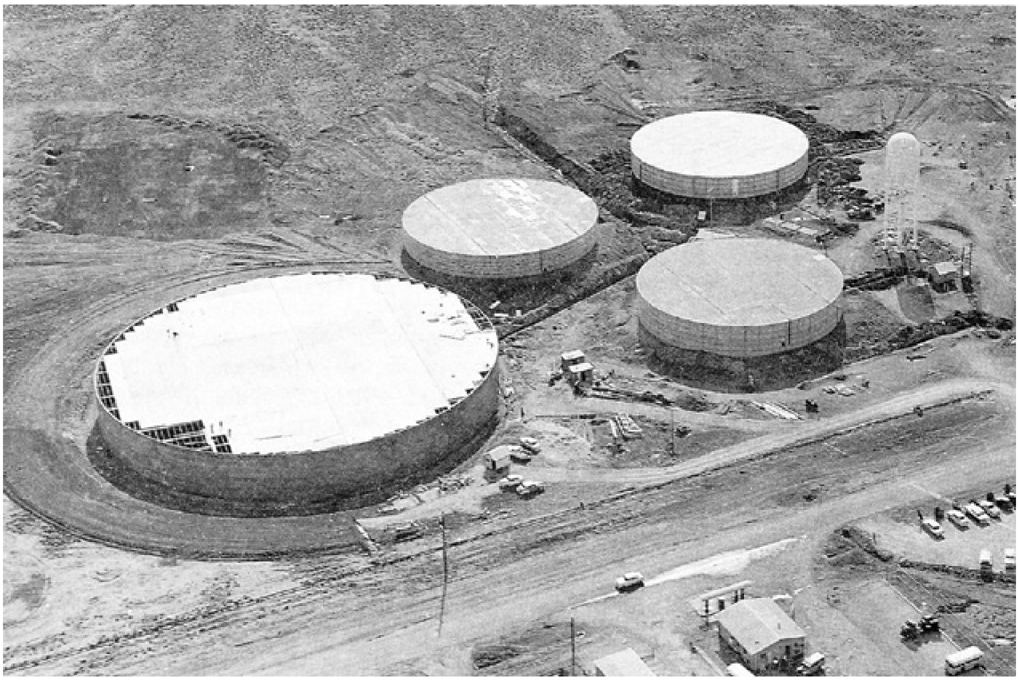
The likely consumption figures were based on the belief that the population of Woomera would eventually stabilise at 2100 people, though ultimately, of course, it grew to triple that number. The personal allowance was set at 273 litres per head per day. Together with all industrial uses, supplies along the route, and leakages, this gave a maximum daily requirement of a little more than a million litres. Gardening and watering of public areas could add nearly half as much again in a hot summer, so the grand total was estimated at 954 kilolitres a day on average, peaking to 1.6 megalitres in the height of summer. The latter figure would be about all the pumps were capable of, but to it could be added the sewer effluent of about 160 kilolitres a week which it was planned to use for tree watering, as well as the three megalitres a week which might be drawn from Lake Arcoona in a good season.[33] As long as the assumptions held the supply was quite lavish, since it well exceeded the average demand over the year.

In March 1948 tenders were let for the supply of 210 kilometres of 254 millimetre steel pipe, and the two successful contractors, Hume Steel of Mile End, South Australia and Mephan Ferguson of Footscray, Victoria, together turned out more than 6 kilometres of the cement-lined pipe each week. By early August 1948 work was underway, supervised by H. T. M. Angwin and construction engineer Gilbert Poole. A total of 230 men worked never less than six days a week on the job and, overcoming delays caused by shortages and winter flooding, laid the pipe almost as quickly as it could be manufactured. At midnight on 28 June 1949, two days ahead of schedule, Murray water at last began to gush from the end of the pipe.

Considering how fragile it was and how quickly the village grew, there were remarkably few hiccoughs in Woomera's water supply. A brief scare arose during the hot summer of 1950 when the pipes were contaminated with a tarry substance which hung in black beads from shower roses and garlanded many unwary heads. Another occurred on the afternoon of 3 January 1953 when all the taps in the northern part of the village unaccountably dried up. Range Superintendent Pither rather tersely asked the Department of Works for an explanation, claiming implausibly (for the failure lasted only six hours) that the 'the result was tragic from the point of view of gardeners', and perhaps more believably, that it could have been calamitous in the event of a fire, and perhaps most of all that it undermined the faith of the residents in the administration.[34] In fact, as Works Director W. T. Haslam reported, at the time of the failure nearly nine megalitres or some six days' supply were still available. Only the village tank was empty, due to an unfortunate coincidence of a closedown of the pumping station at Hesso over the Christmas break, an airlock in the pipeline and most important the unannounced drawing-off in the night of 730 kilolitres for the village swimming pool; the last, he added rather bitingly, despite the fact that, 'the Range Superintendent has been repeatedly requested to co-ordinate times of drawing off water with our staff'.[35] This unfortunate chain of events had no consequences except to raise some blood pressures temporarily. But the episode, trivial in itself, was salutary. It was a reminder that in midsummer the failure of water for more than a few days could mean evacuation and the undoing of the painstaking cultivation of many seasons. And for the next decade the ever increasing population of Woomera pressed relentlessly against the supply. Also the number of drawing-off points along the pipeline for pastoralists gradually grew from seventeen to twenty-six, and although not all were taking their allocation some requests for further connections had to be refused. Still, somehow, with the judicious introduction of more pumps and tanks, Works managed to keep one jump ahead. An additional 9 megalitre tank was approved in March 1953, adding to the existing one in the village and the other of the same size 31 kilometres east of Woomera. Once these tanks were finished and full, Woomera had enough water stored on site to last a month with careful rationing.

By September 1955 the four engine-driven pumps at Hesso had reached the end of their life; they were worn out and in any case their capacity was no longer adequate. The whole system was upgraded, with two new pumps driven by automatically controlled slow running diesels, one to stay on standby. A booster station was put into the pipeline, with electric pumps capable of giving Woomera a limited supply in an emergency. (Some concern was voiced in these years about sabotage. With a figurative shrug of the shoulders, a report admitted that little could be done since not only the pumphouses but the whole pipeline was vulnerable.) The improvements were so effective that pressure-reducing valves had to be put on the pastoralists' taps to avoid waste and leaks.

In 1959 a Department of Works report tried to gauge what the ultimate water usage might be, and after deciding that the needs of about 5800 people could be met by the existing pipeline, started planning even more storage. By the end of 1960 tenders were coming in for a monster 27-megalitre tank. This huge vessel was built of prestressed concrete by the Preload Corporation and was something of an engineering feat in its day. These improvements eventually gave a total capacity of more than 60 megalitres, but in the meantime the critical summer of 1960-61 intervened. For a couple of months there was no slack whatever in the system, and knowing this the Range Superintendent, Dick Durance, had developed a plan for the speedy evacuation of the whole village. All the pumps were working day and night delivering 15 kilolitres a minute into the barely adequate storage tanks. It was not that Woomera households were particularly greedy consumers. In fact they used less than half the amount per head of Adelaide, whose industries caused a big additional demand. But 4300 people still get through a lot of water in an arid climate. The hundreds



Above: Testing the firefighting system at the ELDO launcher. Such systems needed a large water storage capacity.

Above right: The three storage tanks and elevated egg-shaped header tank at Woomera. The large 27megalitre tank was then under construction (1961).

of evaporative coolers alone gulped down 360 kilolitres a day, and even a small lawn had a prodigious thirst. The ranges too needed lots of water on tap. At Lake Hart, Blue Streak and later Europa I used a fire-fighting system which was designed to dump a water blanket of thousands of kilolitres over the vehicle in the event of an accident. The tanks did not refill very quickly. Suppose a second fire started after dousing the first? What if the town grew to 7600 by 1965, as predicted? Only so much water can be forced along a narrow pipe, and that limit was approaching. Luckily the population growth passed the top of its curve over the next few years. Ever since then the supply has been more than adequate, though no one seeing Woomera from the air can possibly forget that the township is a fragile organism in a hostile world. Should that metal umbilical cord attaching it to the distant river be severed, the desert sun is waiting to dry it to a husk and the desert wind to blight its greenery.

FROM PAPER PLANS TO BRICKS AND MORTAR

But the pleasant oasis that Woomera eventually became was no more than a mirage on the horizon for the first few hundred labourers stoically sweating it out amid the heat, the flies and the dust. At first the entire construction camp was under canvas, sleeping two to a tent on straw mattresses, though prefabricated huts started to become available at the Woomera West site not long after.[36] During that first summer of building (1947-48) work had to stop at noon because of temperatures reaching well into the forties. In the New Year the weather became steadily more pleasant during the working day, but as winter succeeded autumn the desert nights grew intensely cold so that the tent dwellers kept dangerous makeshift stoves and even kerosene lamps burning all night. As for the flies, there was some talk of dealing with them by aerial spraying with DDT, but this was given up as impracticable. (In later years trucks spraying insecticide used to pass up and down the Woomera streets and the children of those more trusting times played in the cool mist.) But all agreed that the worst curse of all was the fine red dust which got into everything. Every morning clerks had to wipe down desks and chairs and blow the dust out of files. Sometimes dust storms would rage for hours, reducing visibility to a few metres. One pioneer recalls:

> A preliminary move when going to bed was usually to shake the dust off the bed cover. When it rained (and it rained quite a lot in 1948) the land was transformed into red mud and the absence of sealed roads or paths significantly reduced activities—testimony to this on one occasion was the sight of a pair of abandoned boots embedded in the mud between the living quarters and ablution blocks.[37]

Windblown dust was so hard to bear that some took an almost morbid interest in the phenomenon:

The construction camp at Woomera West in the early 1950s. The workers slept in tents pitched inside the small huts shown.

> If you looked carefully at the ground every little stone, and there were millions of them, had a little pile of fine sand on the lee side of the stone. By three o'clock in the afternoon it was still blowing, but no dust would be coming. Then towards evening, the wind would die down and then all of a sudden it would strike up from the other way, from the south, and you can imagine what happened. All these little piles of fine sand on the one side of the stone were all stirred up again and blown back towards us.[38]

Nor did it seem entirely irrational to believe the country was cursed when sometimes it generated locust and mice plagues of Biblical dimensions. On occasion vast swarms of locusts would plaster themselves all over car windscreens and jam in the radiator honeycombs causing engines to boil. They flew in clouds so dense that they could be tracked on radar though invisible to the eye, giving rise to speculations about UFOs. The mice plague reached monstrous proportions, with thousands of poisoned corpses rotting under the huts. The British servicemen produced the best trap, a dustbin full of water with a pole angled between the ground and the centre of the open top, baited with butter. The mouse would run up the pole tempted by the butter, on which it would slip while turning round and fall into the bin. One night's catch might be a hundred mice.[39]

Despite all these handicaps the work went forward relentlessly. Thanks to the absolute priority eventually given to the project, there was no dearth of basic building materials. Though some items were in absolutely short supply, Woomera seized the lion's share of what was going anywhere in Australia. In February 1948 Premier Playford made the Commonwealth government agree that supplies should be allocated to Woomera before South Australia's, or any other state's, quota was fixed. Having won this concession Playford guarded it jealously, more than once making unexpected searches through the main stores at Woomera West and dressing down the Director of Works if he found any items obtained locally. Although quantities of secondhand timber, iron and so forth were available from army camps being dismantled around the country as well from the Explosives Factory, other scarcer materials had to be ruthlessly expropriated, such as cement intended for the Loxton power station and pipe for the Clare water supply project. What did hamper progress at first was the poor equipment, derived largely from Army disposals. All the transport, which was mostly jeeps, was secondhand and constantly breaking down in the rough conditions. For a while only one jeep out of a fleet of nineteen was on the road, and this at a time when the only repair workshop was housed in a marquee. The first tentage was old, torn and so full of mildew that a tentmaker brought up from Adelaide to repair it refused the job. The food was generous in quantity but sometimes even the skill of the cooks could not disguise the fact that some of the ingredients, like dried egg powder, were old wartime Army rations.

More acute than the materials shortage was the labour shortage, especially of skilled tradesmen. Surveyors, draughtsmen, carpenters, plumbers and the like were reluctant to

Two migrant workers at Woomera in 1948. Migrant workers were known as 'Balts'.

leave the capital cities or even country towns for a desolate site where there were not even enough tents to go round. Nor were they encouraged to do so by the fact that exactly the same country rates were being paid there as in established towns like Gawler; and amenities at Woomera were known to be non-existent. Those willing to brave the conditions, like the only two qualified surveyors, were profiting mightily from the unlimited overtime. So despite protests from the security officers that some were bound to be Communists and ex-Nazi stormtroopers, the construction force was supplemented with men less able, and perhaps less inclined, to jib at what was offered. These were European Displaced Persons, whom Australians, careless of Europe's nationalities, referred to collectively as 'Balts' even though some were actually Poles, Yugoslavs, or Ukrainians. The reason was simple why DPs were available for labour on the Range in the early days: such migrants were compelled to work for a year in a given occupation at a designated site. Having professional qualifications did not free them of this requirement, because in most cases these were not recognised until the local examinations had been passed—Woomera used its quota of migrant doctors as first aid men. At first there was something of a shortage even of migrants. In March 1948 Minister for Immigration Arthur Calwell said that 285 Balts on their way to Australia had already been spoken for by the sugar industry, and 'he did not expect many British migrants would want to work on the rocket range'.[40] (In point of fact, Balts never made up more than 18 per cent of the labouring force, which remained predominantly South Australian and British). In January 1949 when 200 Balts arrived clutching their permitted 16 kilograms of luggage they were regarded with a jaundiced eye by some of their Australian workmates, who noted enviously that the Balts were being given free handouts of tools while Australians had to provide their own. Suspicions were reinforced with the news that one Balt had recorded his intention to work, if necessary, for 'sunshine and potatoes', a cheerful sentiment which naturally did not endear him to the unionists. To the Left, and particularly to the Communists, these refugees were really quislings and Fascists, invited here by the Australian government to speed up 'the headlong war preparations of the American dollar millionaires'.[41] In a series of screaming headlines—'Pro-Nazi Balts with Cameras Roam over Rocket Range Site' is a typical sample—the communist organ Tribune told the world that until publicity had at last made them desist these dubious 'New Australians' had worn their 'Nazi uniforms' to work; and one had gone about boasting that he had been a member of a German aircrew.[42] On closer inspection, however, the Nazi uniforms seemed to shrink down to a pair of blue trousers which may or may not have been Luftwaffe issue. Generally the Balts were thought to be unpredictable and were treated cautiously by the Australians. Some seemed to be skilled in martial arts; others seemed to have imported their hatreds intact and were chiefly

W. Calwell, Minister for Immigration in 1948.

interested in settling old scores. Bouch was once asked by two excited and drunken Balts to adjudicate while one proved his disputed boast that he could kill the other with a single blow across the throat. One man went berserk in the heat and slashed a tent open with an axe; another group tried to burn down the games hut after losing heavily at two-up. Natural problems with Australian idiom lay behind some of the incidents. On one memorable occasion, a group of new arrivals were lined up and warned against the serious crime of drinking in working hours. Halfway through the next blazing afternoon some of this group nearly collapsed from dehydration before it was established all round that 'drink' meant beer in the vernacular, not water.[43]

Not only the Balts had communication problems. They lay behind another incident Bouch had to deal with:

> One day down at the Phillip Ponds camp they rushed up to me and said that some of the others had been picking on a Scotchman. He had chased them around with two bloody big knives. Frankly, I didn't know what to do. So I went over and there's Scotty; his tent was near the kitchen and he was in the doorway with these two big choppers, one in each hand. I had to go up to him and at a distance I talked and talked. I must have talked well because he put the choppers down. So I went in and sat on the bed with him and then he let me take the choppers out. He was all right; he was a Scotchman and he was very broad and they were picking on him. By gee, I had the wind up, I can tell you![44]

By the middle of March 1948 the Press had got wind of the delays and labour shortages and was not slow to put the problems down to incompetent administration. In the view of the *Sydney Morning Herald*:

> The detailed planning and the co-ordination of the jobs have fallen far below proper engineering and constructional standards. Work has been begun in a haphazard way without detailed specifications. There have never been nearly enough engineers employed.[45]

Prime Minister Chifley's immediate response was to say that although there were some difficulties in getting materials in the quantities required the project was 'getting on as well as had been hoped', and the matter would be discussed by the Defence Council when it met in April. A further remark of Chifley's is a striking illustration of the fearful urgency with which Woomera was being built. He said he was very worried by the political situation in Europe, and thought it was deteriorating. Though he would not speculate about when war would come, he left no doubt that to the government's way of thinking no task was of higher priority than getting Woomera finished. Some days later Cyril Chambers, Minister for the Army, and Senator Armstrong, Minister for Munitions, accompanied by federal Labor members went, or were sent, to check on progress for themselves. What they saw must have pleased them, for when the Defence Council did meet on 20 April 1948 it recorded itself satisfied. By this time 8 kilometres of railway had been laid by the hardworking No. 2 Airfield Construction Squadron (2ACS) which had finished the main airstrip of 1800 m and had another well underway. The telephone line now joined the site with Port Augusta and points south and the outline of the road plan was at least visible. At this rate the deadline of the building program would be met and the first experimental firings could be made in three years' time.[46] In fact a press release about this time announced that some 'top secret experiments' had already begun; these were probably the high altitude parachute trials at the beginning of the year. Within the organisation itself, however, feelings were considerably less sanguine. A Superintendents' meeting early in May was told that hardly any of the living quarters and associated services would be finished by the end of the year and since the decision stood that no staff would be called forward for Woomera duty until living quarters were ready for them, hold-ups seemed to be inevitable.[47] Consultant Engineer Wynne-Williams gave full vent to his frustration:

> The revision of the estimates has emphasised the failure of our organisation during the past eighteen months to plan the development of the Range in a rational manner. The trend of events was becoming evident about seven months ago and the pre-planning scheme which was then devised was an attempt to avoid the position getting out of hand as it has now done. The pre-planning scheme failed through lack of appreciation of its purpose or any determined effort to put it into practice . . . The original staff at Salisbury has contributed little to the work of planning. In two major items of the project responsibility for decisions was deferred until the arrival of 'experts' from the UK. In each case the 'experts' contributed nothing that justified the delay. In one case the layout had to be revised after the 'experts' had returned to the UK; in the other case the scheme they favoured was adopted.[48]

This bitter broadside probably overstated its case, for even then the situation was beginning to ease with an urgent recruiting drive in Britain in the second half of 1948 by the efficient W. T. Haslam, who had supervised the Explosives Factory construction and was now Commonwealth Director of Works in South Australia. Within a month he processed 600 applications from architects, surveyors and engineers, and he had recruited a hundred for work on the project by the time he returned to Australia in mid-September 1948.

In the winter of 1948 the village site presented a scene of purposeful chaos, like a disturbed anthill. Tracks were scrawled everywhere across the plateau, but buildings in all stages of construction were rising alongside some of them, so that a town plan was becoming visible. Piled everywhere were big dumps of every kind of material, some of it secondhand, and each week two special goods trains added another 750 tonnes of stores to the stockpiles. Bulldozers and excavators were noisily at work, ripping trenches through the gibber plain. A quarry was beginning to eat into a hill of quartzite, to supply the hundreds of thousands of tonnes of crushed metal shortly to be used for concreting and sealing the airport runways and roads. The army and air force construction camps at Koolymilka and the airfield still consisted of many hundreds of men plus a few women working as waitresses, living under canvas. At Woomera West, however, tropical style shanties of wood and iron had arisen, encasing the tents which were left erected inside. (The not infrequent cyclones ruled out a permanent tent encampment, though an MP later put the arrangement down to a cunning subterfuge by the workers to continue drawing their hard-living allowances.) These huts, 'air-conditioned' with gauze around the tops of the walls, were supposed to be cool in summer and warm in winter; in fact they were neither. By the end of the year fifty huts were up in the village to house the embryonic administration and the two messes where single men lodged and ate.

By this time breathless reports were being aired that Woomera was a 'workers' paradise', and that a 'gold rush' of men were leaving Port Augusta for the new style diggings every day; private contractors were said to be making an astonishing £90 a week. Even the

An early vertical view of Woomera under construction, with the north-east corner at top right.

servicemen of the construction squadron were, according to a glowing account from the Department of Information, living in unaccustomed comfort:

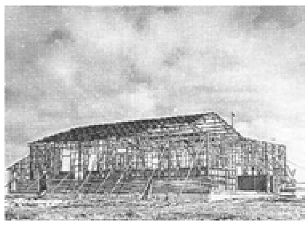
> The private entertains you in his own tropicalised cabin with curtains on the louvre windows, a bed with sheets and bedspread, and to dispel the last shred of illusion of the Army As We Knew It—a reading lamp over the bed![49]

But as usual in such cases the truth was more modest. The earnings of most workers were closer to £13 for a 48-hour week, and the turnover of labour was very rapid. Knowledgeable men judged conditions were even worse than they had been at another isolated site—Canberra. The isolation, the homesickness, the sheer awfulness of the place got to many, and were not easily ameliorated by three open air movies a week and a multitude of two-up schools. A run of dreary days with a cold southerly wind, or a cut in the tobacco and beer ration, would be enough to send another dispirited group drifting back to more familiar scenes. In the single year 1949-50 every other man had to be replaced. However, conditions were usually peaceful and a single mounted trooper was the only visible presence of the law. The discontented, perhaps aware of the futility of union activism on a site protected by a special Act of Parliament, simply voted with their feet.

By early in June 1949 Senator Armstrong was promising that work was now far enough along for some 'rocket launching' to take place soon, though he hastened to add that it was to test trials instrumentation, not the performance of rockets themselves. Invitations were issued to journalists to witness what was offered as the 'first rocket trials' on 3-4 November, and their accounts give a useful impression of what Woomera had evolved into by the end of 1949. The trials were very much a public relations exercise. They consisted of firing fourteen of a small 76 millimetre rocket, a type used in their thousands during the war, although apparently an attempt had been made to arrange something more spectacular. Embarrassingly, and ominously for those who believe in omens, the Minister's first two attempts at igniting these rockets failed. But despite this contretemps the reporters found that the progress in construction had been remarkable, from straggling lines of tents to 'neat red, green and blue roofed family houses' in a mere sixteen months.[50]

THE VILLAGE COMPLETED

In the first years of the 1950s Woomera continued to grow rapidly: its population was 3000 in August 1950, and 3500 (including 200 families), six months later. But by about 1954 the village had taken on its mature shape and though new buildings were added intermittently for many years its general appearance remained much the same until it began to contract in the 1970s. In shape it is a rough rectangle with an area of about 2.5 square kilometres, cut into quarters by two main avenues. Off these main thoroughfares run U-shaped streets of houses and flats, the name of each street beginning with the same letter as the avenue off which it runs. Grouped loosely around the avenues' intersection are the main public facilities: the store and a few other shops, theatre, churches, pools, post office and hospital. By 1954 the amenities were certainly better than those of any other township of Woomera's size. Most of the houses and messes were finished by then, and all buildings were sewered with electrical and water reticulation. The town centre would be developed further as Butement Square, but one could already shop at the community store (later ASCO) which had been operating in a converted hut since February 1951 but which opened on 28 April 1954 in its new premises with an associated bakery, dairy and butcher. The town could also boast an ice cream and cordial factory, a courthouse and cell block, a police and fire station, a picture theatre, a partly built post office, a laundry, a telephone exchange and a women's hostel. The radio station 5WM had been on air for nearly three years. A new pool was opened in 1954, as well as tennis and basketball courts, and a croquet lawn was being built. The first interdenominational church, known as the Church Hall and used as the first school, had been consecrated in September 1949. Later it was replaced by three separate churches.



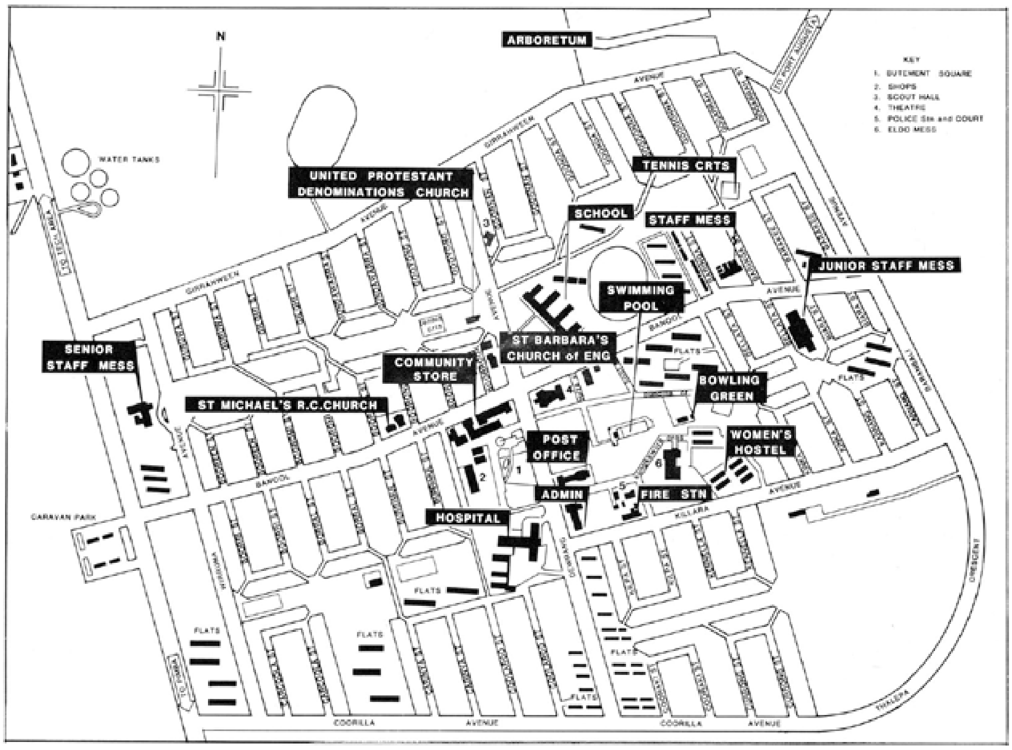
The first large building under construction at Woomera. Although intended to be a gymnasium, it was used as a temporary picture theatre.

Right: The old Woomera hospital.

Far right: State Governor Sir Willoughby Norrie visits a patient in the old Woomera hospital in 1951.

The first hospital was a brick building which later became the civic administration centre. Officially it took twenty patients, but later up to thirty-five beds were squeezed in, and two adjacent prefabs in Kinka Street were used as midwifery wards. The doors of these houses were too narrow to take a stretcher, and the women in labour had to be passed through the windows. This hospital had no slack at all to cope with, say, a serious explosion at the Range with many casualties, and a purpose built hospital was given top priority after the initial phase of building was complete. Built in the village centre at a cost of more than half a million pounds, the 'new' hospital had forty-six beds, with all the usual facilities: midwifery, mothers and babies clinic, X-ray, casualty, and nurses' quarters. A curiosity of its layout is that the wards lie on either side of the pan rooms and other services. Because of the supposed risk of infection this scheme was contrary to the health regulations, but the Department of Supply gave the medical staff a free hand in the design, and they had it built just the way they wanted it.

Life at Woomera was civilised now, at least in its basic material conditions. But the texture of life consists of more than being gainfully employed, extremely well fed and tolerably housed. With what success did the people of Woomera pursue their unalienable right to the pursuit of happiness in the years of the project? This theme must wait for a later chapter.



The compact, mature (1965) shape of Woomera, the town created in an open, treeless semi-desert to house the range staff. Note the U-shaped residential streets, designed to discourage through traffic, and the central shopping and civic facilities.

Notes and Sources

1. The opinion of Vic Surman, a Department of Works and Housing employee who has lived in Woomera continuously since 7 August 1947 and who at the time of interview (11 August 1983) probably held the residency record.
2. These two possibilities were outlined by Evetts himself, as reported in the minutes of the Long Range Weapons Board of Administration meeting No. 4 of 24 March 1947. The formal decision to pull back the rangehead had been taken at meeting No. 1 on 31 January 1947.
3. Letter of 26 May 1947 from Director SA Department of Mines to Controller General of Munitions N. K. S. Brodribb. Australian Archives accession no. MP 1748, file GW/ W/5 part 1.
4. Minute of 2 June 1947 from Consultant Engineer to Chief Executive Officer J. F. Evetts. AA MP 1748, file GW/W/5 part 1.
5. 'Rangehead for rocket tests', Advertiser, 5 July 1947.
6. Minutes of Long Range Weapons Board of Administration meeting No. 5 of 17 April 1947.
7. Reminiscence of Air Commodore N. H. Fresson in a letter of 20 August 1985. Various other inaccurate accounts of the naming of Woomera have been published. For example, J. Clark, an administrator at Salisbury in the early days, has it that the name was suggested by a young woman employee at the base. See 'The Woomera experience', Army Quarterly and Defence journal, 107 (July 1977), p 354.
8. 'Woomera' (editorial), Advertiser, 7 July 1947.
9. Charles Duguid, 'Naming of rocket range' (letter), Advertiser, 10 July 1947.
10. 'RAAF men seek discharges', Advertiser, 3 October 1947. Don Grace of Woomera recalls that the beer was supplied only with the caps off, presumably to eliminate the risk of its being stockpiled for one big weekend drunk. Interview of 1 August 1983.
11. 'Unions seek ban on rocket plan', Advertiser, 15 March 1947.
12. 'Union ban on rocket range', Advertiser, 12 May 1947.
13. Fred Alexander, From Curtin to Menzies and After: continuity or confrontation? Nelson, Melbourne, 1973, p106.
14. 'BWIU concern over Aborigines', Sydney Morning Herald, 13 May 1947.
15. The statement was printed in full in Tribune, 16 May 1947.
16. Alf Watt, Rocket Range Threatens Australia, SA State Committee, Australian Communist Party, Adelaide, [1947], passim. This pamphlet was so significant in the eyes of the project's Board of Administration that it ordered six copies from Adelaide, though it is hard to imagine what it did with them all.
17. 'Unions reject ban on rocket range', Advertiser, 29 July 1947.
18. 'Storm of protest on Ebo [sic] ban: war attitude recalled', Sydney Morning Herald, 13 May 1947.
19. 'Communists attacked by ALP; "Acting for foreign power",' Sydney Morning Herald, 15 May 1947.
20. 'Threat to defence' (editorial), Advertiser, 12 May 1947.
21. The Left regarded Evatt's support of the Act as apostasy. A good cartoon in Tribune (1 July 1947, p 3), over the caption 'Goodbye Dr Evatt: you could have had a place in history with us!' showed the Attorney-General shying away from the accusing glare of the Tolpuddle Martyrs and stalwart shearers and scuttling off down a lane labelled 'Right' with the crumpled Bill under his arm.
22. 'Guard against sabotage', Advertiser, 4 June 1947. The OED simply defines 'strike' as 'any refusal to work until some grievance is met'—leaving it clear that the grievance can refer to any matter from the most concrete to the most abstract.
23. Tribune, 17 June 1947.
24. Reported in Tribune, 20 June 1947.
25. Charles Duguid, 'Source of opposition to range' (letter), Advertiser, 5 June 1947.
26. Memo dated 19 August 1948 from CIS to the Security Officer, Salisbury; additional information from a report dated 19 August 1948, file S1493/7. Cavanagh recollects (interview of 8 July 1983) that neither he nor his fellow unionists were ever given any precise reason either, but he believed that permission was really denied simply because they had lent vocal support to moves to stop the Range being built. He finally gained entry to Woomera in 1950 after agreeing that he would not try to address the workmen.
27. As quoted in 'No union visit to range', Advertiser, 25 August 1948.
28. Looking back on the dispute, Cavanagh allows that there was never any proof of security interference, but he records-that he 'received more complaints of conditions at the site than I have ever received from any other construction project . . . when I eventually visited Woomera the site conditions including living conditions at Koolymilka were the worst I had seen at any building camp'. Letter of 27 June 1983.
29. Minutes of the LRWO(A) Executive Works Panel meeting No. 12 of 1 December 1947.
30. Minutes of the Long Range Weapons Board of Administration meetings No. 1 of 19 February 1947 and No. 2 of 27 February 1947.

31. Letter dated 26 May 1947 from Director SA Department of Mines to Controller General of Munitions N. K. S. Brodribb. AA MP 1748 file GW/W/5 part 1.
32. Tribune, 6 May 1947.
33. Memo from Main Works Committee, Department of Works and Housing Chairman, to Chief Executive Officer Evetts of 4 February 1949. AA MP 1748 file GW/W/5 part 1. In fact the plan to draw an extra allowance from Arcoona was never followed up. Pumping stopped at the end of April 1950, saving the project £200 pa paid to Arcoona Station in compensation, and the pipe was pulled up.
34. Letter dated 19 January 1953 from Range Superintendent to Chief Superintendent LRWE. File A15 part 2.
35. Report dated 17 February 1953 from Director of Works to Chief Superintendent LRWE. File A15 part 2.
36. 'Rocket site anxiety', Advertiser, 4 December 1947.
37. Undated reminiscence of Terry Goonan, an administrative officer at Woomera for many years.
38. Reminiscence of Hartley Bauer, then a warrant officer and one of the first servicemen on the site, in an interview of 15 July 1983.
39. Undated reminiscence of Colonel Goodeve-Ballard.
40. 'No migrant workers', Sydney Morning Herald, 17 March 1948. The proportion is taken from figures supplied by the Federal Minister for Works and Housing, as quoted in '360 DPs working at Woomera', Advertiser, 4 June 1949. The same story reported that many English-language classes were meeting, with teachers recruited from among the engineers and clerical staff.
41. Tribune, 28 August 1948. On the other hand, at least one Balt is said to have been deported for labour agitation at Woomera.
42. Tribune, 31 July 1948. At least one of Tribune's stories on Woomera was submitted to the Crown Solicitor for an opinion as to whether it breached the Approved Defence Projects Protection Act. The opinion was that though it was 'a gross mis-statement of facts . . . written with political bias', it did not.
43. Anecdote of Aub Reilly, an Army warrant officer who was working on line construction at Koolymilka at the time.
44. Anecdote of Alan Bouch, Project Officer 1947-51, in an interview of 3 October 1983.
45. 'Delay feared in work on rocket range', Sydney Morning Herald, 16 March 1948.
46. 'Progress at Woomera', Advertiser, 21 April 1948.
47. Minutes of Superintendents' meeting No. 4 of 5 May 1948.
48. Minute dated 25 August 1948 to Chief Executive Officer Evetts. AA Accession MP 1746, file GW/5P/10.
49. John Loughlin, 'British rocket tests in Australia: tempo rises on desert proving grounds', Commonwealth Department of Information release of November 1949.
50. 'Woomera rockets go up today', Advertiser, 4 November 1949. In fact the first 76 mm rocket had been fired at Range F in March.

9 Flying for the project: *Transport and Trials*

THE RAAF PRESENCE

Right from the beginning all three Australian fighting services played their part in the Woomera story. During Evetts's pioneering survey visit in April 1946 he had administrative support from the Army and it was the RAAF that flew his party in the search for a Range site. On the Guided Projectiles Committee set up at the time were representatives of all three services, and they continued to serve on the later Board of Administration and the Board of Management. These representatives were no figureheads but experienced senior officers like the Army's Major-General L. E. Beavis and the RAAF's Air Vice Marshal E. C. Wackett, both of whom contributed much to the project in its infancy.[1]

At the outset the federal Cabinet had ruled that servicemen should be integrated into the new Long Range Weapons Organisation (LRWO) to gain experience with guided weapons. In practice this did not happen to any extent at the Salisbury base; but it certainly happened at Woomera in its first few years. In 1947 the Army set up their first headquarters in a camp near Phillip Ponds at a time when the future town of Woomera was nothing but an empty stretch of gibber plateau. Two years later an integrated tri-service Range establishment was created to administer the village and to man the Ranges as they were established. By about 1955 the servicemen in the Woomera administration had been largely replaced by civilians except for the top position of Superintendent, which until 1968 was filled by an officer of the three services in turn. At the Range, though, the Army maintained a presence until 1973. The Army Guided Weapons Trials Unit was responsible for missile preparation and launching and, initially, for radar operation and maintenance.

Despite the key part played by the Army, and to a lesser extent by the Navy, it was the Royal Australian Air Force which made the greatest armed services contribution to the joint project throughout its existence. Of the RAAF's many services to the project, three were of vital importance. The first and earliest was the construction by No. 2 Airfield Construction Squadron (2ACS) of an airfield at Woomera in the first few months after its site was chosen. The second was to airlift men and materials for Woomera and elsewhere. The third was to fly the aircraft that dropped bombs and took part in other Woomera trials, and to operate the pilotless target aircraft at which guided weapons were fired.

Until 1955 the RAAF transport and trials units formed one arm of the Long Range Weapons Establishment. They were known for the first few months as the Air Establishment (LRWAE) and then as the Air component of LRWE. This arrangement was not a very happy one as it tended to cut across the much stronger ties of RAAF hierarchy, and it was largely abandoned in the radical reorganisation from which the Weapons Research Establishment was born in 1955. At first the Air component was located about 50 kilometres from Salisbury at the old wartime Mallala airfield, until in 1954 a new home, Edinburgh Airfield, was built for it next to the Salisbury base. Edinburgh was used entirely for joint project flying until the activities at Woomera started to decline in the mid-1960s. In the reorganisation of 1968 the airfield was bequeathed to the RAAF, although it continued to support the few remaining trials programs. Edinburgh is now a major operational air base and the home of the RAAF's fleet of P-3C Orion maritime patrol aircraft.

FINDING A HOME FOR THE AIR COMPONENT

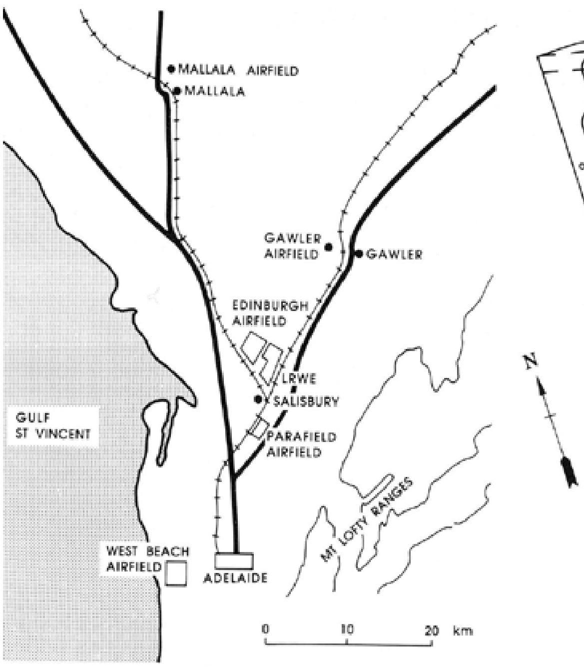
There had been little hesitation in taking over the explosives factory as an obvious place for the base establishment nor in deciding where to put the Range, apart from the early shift from Mt Eba to the Pimba area. Not so with the third of the trio, the Air component—it was to be seven years before it settled in its permanent home at the Edinburgh Airfield.[2]

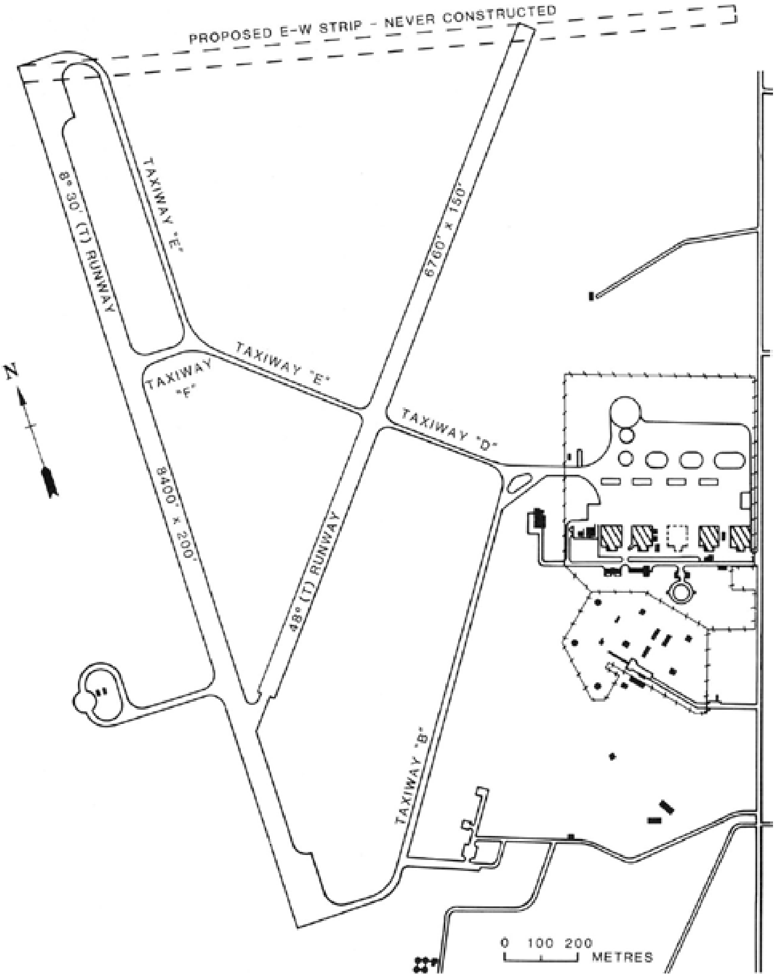
It will be recalled that the Evetts Report had spoken of using an old RAAF aerodrome at Gawler, then a small country town 30 kilometres north of Salisbury. Nothing came of this proposal, partly because Gawler had no buildings but mainly because the Mount Lofty Ranges approach too closely at Gawler to give room for the enormous 8 kilometre runways thought to be required by the expendable bomber concept which came to nothing. There were other alternatives. Close to Salisbury was the civilian airfield of Parafield, which handled all the air traffic of Adelaide. (The city's airport at West Beach did not then exist.) But Parafield would not really do. It tended to flood and was unsuitable for heavy aircraft because it had only a grass surface and was too small to take the long runways required. Security might also be a problem at Parafield.

The choice soon fell on an old Empire Air Training Establishment at Mallala, a tiny township 48 kilometres from Salisbury. This had been occupied during the war by No. 6 Service Flying Training School. It had been built in 1941, but not used since 1945, and consisted of a number of wooden huts and hangars and grass surfaced runways. The runways needed paving to give all-weather operation and to suit future jet aircraft, and the temporary wartime wooden buildings would have to be replaced; but Mallala would do as it stood for the very early stages of the project. The decision in favour of Mallala was made by the Board of Administration on 5 June 1947. This was after its Air Requirements Committee had inspected both Gawler and Mallala, and the Department of Works had reported that the soils in the Mallala area would allow paving of the runways, and the later extension of one of them to 8 kilometres for the heavy expendable bomber.

RAAF Station Mallala was founded on 1 July 1947 as the nucleus of the intended LRW Air Establishment. But that same month the whole idea of adopting Mallala as a permanent centre was strongly challenged from the British end. During his visit to Australia, G. W. H. Gardner, Director of Guided Weapons RS&D, pointed to the advantages enjoyed by RAE Farnborough in having its own airfield close by. Salisbury too could have an adjacent airfield for no more—perhaps less—than it would cost to rebuild one far away at Mallala.[3] Gardner inspected what had been the old cordite area of the munitions factory and thought a suitable airfield could be established there if some of the paddocks outside the boundary fence were acquired at once, with others reserved for the future long runway. This would give plenty of room for the hangars, and the cordite area already had some good solid brick buildings on it which could be converted into offices and living quarters for the RAAF airmen.

The RAAF Station, Mallala, in 1950 when it was the interim LRWE airbase.





Above: LRWE Salisbury and nearby airfields. Although Gawler was proposed originally, the LRW airbase was first established at Mallala and later shifted to the new Edinburgh airfield at Salisbury.

Right: Edinburgh airfield layout. Originally it was to have three runways, but one was never built and the 48-degree runway was not paved.

At its next meeting on 7 August the Board of Administration agreed to look closely at this idea. In the meantime Mallala would be regarded as a temporary expedient, to be abandoned after perhaps three years and therefore to be given only the minimum practicable upgrading. Thus it was that within four months the pendulum had swung from Gawler to Mallala and then on to Salisbury. Here opinion stabilised, but almost seven years went by before the new airfield was ready for limited use.

One problem to be sorted out was that the Salisbury airfield would be within 10 kilometres of the existing civil airfield at Parafield. Although the airlines would soon be transferring to West Beach, small aircraft, some without radio, would continue to use Parafield. There could be air traffic control problems. At one stage during the long discussions between the RAAF and the Department of Civil Aviation it seemed Parafield might have to close altogether and another site found for small aircraft, but in the end simultaneous operations were allowed and caused no difficulties.[4]

At this stage the Salisbury airfield was no more than a proposal. The first step was to seek the approval of the Australian government, which, under the Dalton formula of the still unsigned joint project agreement, would have to pay for it. On 3 March 1949 the Board considered a submission from Evetts recommending construction of a permanent airfield at Salisbury, including accommodation for the Air component in the cordite area. Apart from the convenience and economies of operating so close to LRWE Salisbury, the estimated construction cost of £1.1 million was £360 000 less than upgrading Mallala to the same standard, mainly because the existing cordite area buildings were in solid brick while those at Mallala were cheap temporary wooden structures which would have to be rebuilt. A sympathetic Board was soon convinced by these cogent arguments and decided to recommend the plan to the Minister for Supply.

Ministerial approval came on 27 May 1949 and, over the next months, detailed specifications were prepared and sent to the Department of Works along with a requisition for £1.1 million. But later in the year Works came back for more. Labour costs had risen recently and LRWE wanted some expensive changes in runway layout. So the estimates were revised, and the new figure of £1.4 million was submitted to the Minister in May 1950. This time it took two years before the increase was approved.

In the meantime 'pre-planning' at LRWE was completed, followed by detailed design by Works and Housing. Inevitably there were changes in design. For example, the airfield was originally to have three runways oriented approximately N-S, NE-SW and E-W. Works and Housing suggested early in 1951 that two runways should suffice, giving tolerable cross-winds for over 95 per cent of the time. LRWE agreed to defer the E-W runway, and in fact it was never built. After lengthy discussions with the Departments of Air and Civil Aviation, a further decision was made to pave only the major N-S runway, making do with a consolidated earth grassed surface for the NE-SW runway, to be paved later if necessary. It never was.[5] Another change was a relocation of the hangars which originally were planned to be inside the cordite area, connected to the runways by a long 1.5 kilometre taxiway. In the end they were built on the other side of the old boundary road, much closer to the runways. This shift avoided the expense of rebuilding the high voltage power line that still runs alongside this road.

Work began first on the extensive building alterations and the new buildings in the cordite area needed to accommodate the RAAF staff of the Air component. There was a long delay in starting work on the airfield itself because of design changes and shortages of labour and earth moving equipment, much of which was then being used in the construction of the West Beach airport. At the time the Minister for Supply, Howard Beale, first announced to the press[6] that a new aerodrome was being built near Salisbury to replace Mallala (May 1951), preliminary fieldwork on the airstrips had only just started.

While this work was proceeding the Australian government was still considering the submission for the additional £300 000 estimated in August 1950. By late 1951 a submission from Beale had reached the Cabinet Committee on Defence Preparations. The submission summarised the old arguments for choosing Salisbury rather than Parafield, Mallala or Gawler, and pointed out that about £340 000 had already been spent on or committed to the Salisbury site. Nevertheless the Cabinet was not convinced that Gawler should be ruled out, and deferred a decision until the Air Requirements Committee had reassessed this site. This Committee did so in February 1952, and confirmed the hazards of using the two airstrips at Gawler, one oriented towards the township and the other heading directly towards a nearby range of hills. Further, the old wartime paved runways were now unsuitable and new runways would be needed. The Cabinet Subcommittee sensibly accepted the strength of these arguments and in March 1952 Cabinet gave the go-ahead for the Salisbury airfield, but ruled that the £1.4 million estimate would be a limit, with no further funds to be approved on any account.

Grading and forming the airstrips had been held up pending this decision, and also crushed rock was in short supply. Work did not get into full swing until the end of 1952 but then it went ahead quickly, with the main paved airstrip built using day labour. Another achievement was that construction costs at the time of its completion in mid-1954 were kept within the limit imposed by Cabinet, although this meant trading off the inevitable cost rises by deleting some of the less vital items and by using temporary runway lighting. Later the Airfield was to be further developed for air-to-air weapons trials and later still for RAAF requirements outside the joint project, so that the final capital cost of Edinburgh eventually far outstripped the £1.4 million limit set in 1952.

The plan was for HRH the Duke of Edinburgh to name and open the new airfield in March 1954, during the first post-war Royal visit to Australia. The Duke and his party would then take off from the new airfield and fly to Woomera for an official visit, and there was pressure to have the main airstrip and other necessary facilities ready in time. This was achieved.

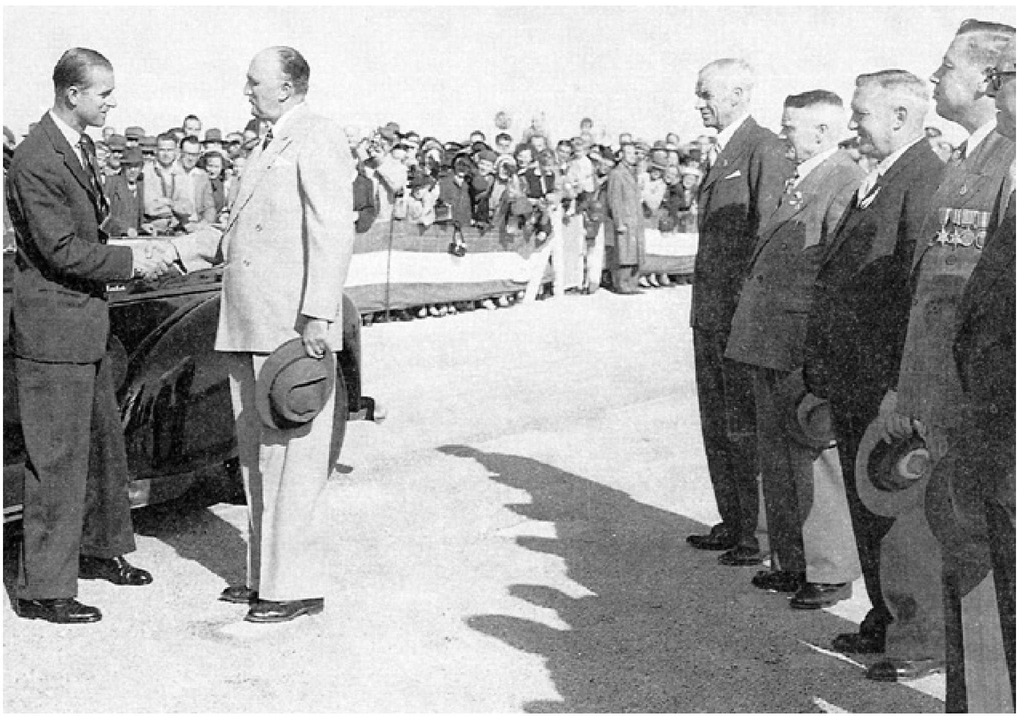
One other detail that had to be settled before the opening was the name for what until then been referred to as the Salisbury Airfield. In an attempt to maintain the tradition of using Aboriginal names, the Melbourne headquarters again got out the glossary held by the Board Secretary, Eric Cook. In January 1954 the Minister and Royal Tour authorities approved the choice of 'Koolimurra', and LRWE was asked to prepare a suitable plaque. Curious about the meaning of the word, Chief Superintendent Bareford asked LRWE librarian Joan Holland to check it out; and she in turn referred the query to Norman Tindale, Curator of the South Australian Museum and an authority on Aboriginal culture. Tindale advised that the name was a barbarous version of *kulimara*, a word used only by Flinders Ranges natives, and meant 'pine tree hollow'. Bareford promptly sent a teletype to Melbourne with this news, adding that the name could easily be confused with 'Koolymilka', a name often applied to the nearby Evetts Field airstrips. He ended the teletype with a remark that 'as there are more Welshmen in GW than Aborigines suggest we employ a Welsh name which I shall be glad to supply on request'.[7]

Melbourne headquarters tried again. The Minister approved a new design for the plaque, which was now to bear the euphonious name 'Mirrabooka'. After checking once again with Tindale, Bareford retorted that the authentic version of this name was *mirrarabuka* which means 'stinking swamp'. By this stage Headquarters was ready to give up on Aboriginal names. They intended now to ask for Royal assent to a much more sedate choice, 'Edinburgh Airfield'. But would it be forthcoming? As the opening was now only three weeks away two plaques were made: one bearing the name Mirrabooka and the other Edinburgh. In the event the Duke did agree to his name being used and the appropriate plaque now records the opening of Edinburgh Airfield on 22 March 1954. The rejected 'stinking swamp' plaque was preserved and eventually found its way to the officers' mess at Edinburgh, where it now adorns the Contrails Bar.

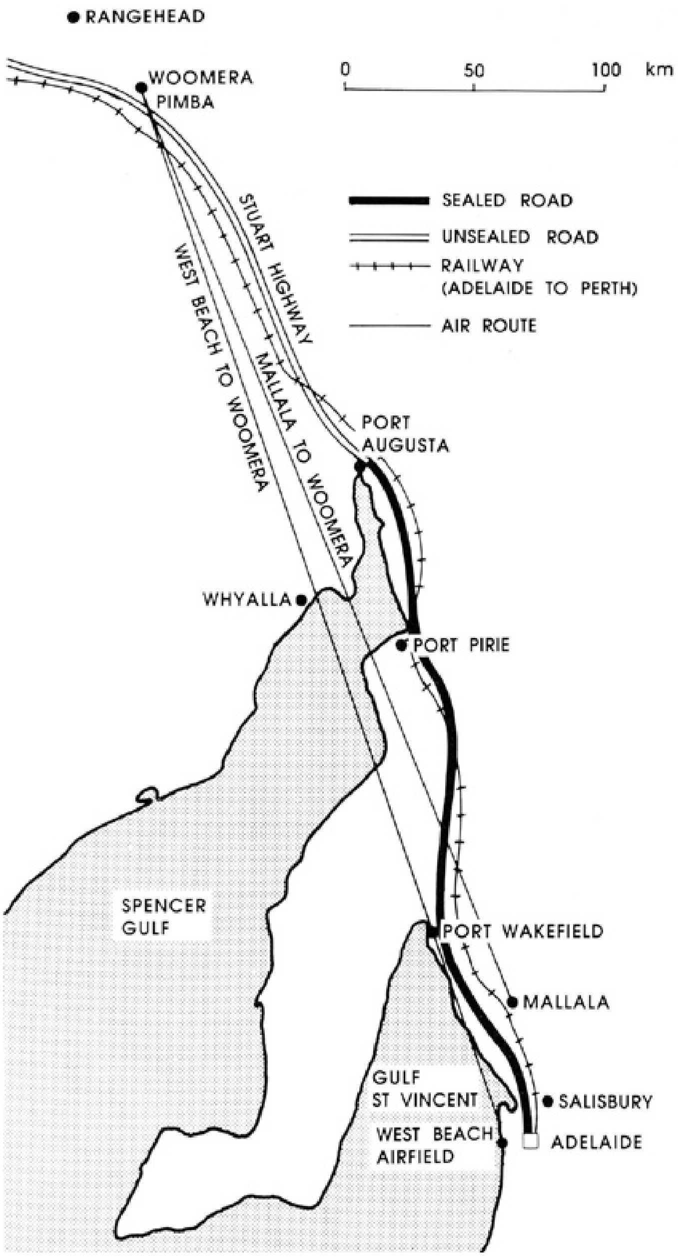
The rejected 'Mirrabooka' plaque, originally intended for the new airfield.

The opening was a ceremonious occasion. In front of a large crowd of LRWE, RAAF and construction staff, and after a long speech of welcome that had the crowd fidgeting, Minister Howard Beale presented the Duke of Edinburgh to a line of eighteen officials. When the moment came, the Duke's response was a model of brevity. He drew the blue velvet curtain to reveal the plaque and spoke for six seconds, 'I have much pleasure in declaring this airfield open, and naming it the Edinburgh Airfield'. Moments later he was in his car being whisked off to an aircraft waiting to fly him to Woomera. Stunned by the sudden climax, the crowd momentarily forgot to cheer.[8] Why was the Duke so laconic? According to one of the party who flew to Woomera with him, he had said previously he did not intend to make a long speech and the crowd would not want to hear one anyway.[9] According to Miss MacDonald, Bareford's secretary at the time, he was irritated by the line-up of officials, many of whom had nothing to do with the new airfield and some of whom he had already met elsewhere.[10] Perhaps he repented of his rather curt behaviour, for he made amends by paying a surprise visit to Salisbury a few days later without any fanfare.

It appears that the Duke thought the new name would not stick. The story goes that as the aircraft circled following take-off for Woomera, he looked out the window and asked 'What's that airfield down there?' The prompt reply to his trick question was 'Salisbury Airfield!' 'There you are', he said triumphantly, 'I told you they'd never call it Edinburgh!'[11] But he was wrong, for the old name was soon forgotten.



The Duke of Edinburgh arriving to open the airfield that bears his name. He is welcomed by the Minister of Supply, Howard Beale, and a long line of officials.



The airlift to Woomera was essential to the project. The road north of Port Augusta was rough and impassable when wet. The rail connection was slow and there was a break in the gauge.

THE WOOMERA AIRLIFT

The 480 kilometre road connection between Salisbury and Woomera was much used for transporting freight, but it was anything but a fast highway. The last 160 kilometres north from Port Augusta were nothing more than graded dirt, rough at the best of times and impassable in wet weather. Further north from Woomera roads were generally only dirt tracks. The rail connection to Woomera was slow and there was a break of gauge at Port Pirie. Accordingly, reliable and efficient air communications were essential to the success of the project from the beginning. In 1947 civil aviation in Australia was only just establishing itself again after the War, and so it fell to the RAAF to supply the air transport.

To service the project, No. 2 (Communication) Squadron, a new RAAF unit, was formed at Mallala in June 1947. The following month it got its first aircraft, an old Avro Anson Mk I, which made the first return flight to Woomera. This was the start of a regular RAAF courier service that was to form an essential communications link in the early years of the project. The following March the unit was renamed No. 34 (Communication) Squadron, reviving the name of a wartime transport squadron that had been hurriedly formed in Darwin in February 1942, just after the first Japanese air raid, and had later served in the South Pacific. The Squadron maintained the Woomera airlift until it was disbanded at Mallala on 28 October 1955, passing over its duties and aircraft to another RAAF unit at Edinburgh.

This Vickers Viking, supplied by the UK, was little used as it was reserved for occasional VIP flights.

Early passenger flights in the sidesaddle Dakotas were excruciatingly uncomfortable.

The plans in 1947 were for the Ministry of Supply to provide all the transport aircraft. These were to be three Bristol Freighters, two smaller Avro Anson Mk 19 aircraft and a Vickers Viking for carrying VIP passengers in more comfort than the Bristol Freighters and Ansons could manage. The Viking and Ansons came in December 1947 but the Bristols were delayed, first because of the temporary cloud hanging over the project during the cancellation crisis at the end of 1947, and later because of hesitations over which version to order.[12]

In order to get the transport service started quickly three RAAF Dakotas were ferried to Mallala, and these supplied the regular Salisbury-Woomera courier service until the Bristol Freighters arrived in May 1949. The Ansons were used for special flights and the Viking for VIP work. The Dakotas were excruciatingly uncomfortable. In fact they were still fitted out for their wartime role of carrying paratroopers, who at least had had their parachutes to sit on. The cabin was unlined and the side saddle seats were nothing more than a narrow shelf of aluminium or canvas webbing along each side, with no back support except for the exposed stringers and pipes. Here in the cold and the noise the two lines of passengers would squat miserably, staring at each other across crates of equipment chained to the floor.

The misery of the Dakota flight was only one element in these early tedious and uncomfortable trips to Woomera. They started at 7 a.m. when a spartan bus left Adelaide. Passengers leaving from Salisbury were driven to meet the bus, but those living in departmental houses in Blair Athol and Enfield North were expected to walk through unlit and unmade streets to the Main North Road and wait for it there: no joke on dark, rainy winter mornings while burdened with luggage for a week's stay. Then followed the long ride out to Mallala and about an hour of kicking one's heels waiting for the Dakota to load up. It often happened that passengers, already queasy from the uncomfortable bus trip, were airsick long before they reached Woomera. To cap it all off, the final part of the trip from Woomera airstrip to the village was often in the back of a truck under a canvas canopy, with dust from the unsealed roads pouring through the open back. The grimy passengers arrived at Woomera just in time for lunch but with little appetite for it.

The trip was so bad that at least it could only get better. The first improvement was the arrival of the Bristol Freighters in 1949, and then the following year the Mallala bus trip was replaced by a short ride to Parafield, conveniently situated about half way between Adelaide and Salisbury. The passengers were picked up there by a Bristol flown from Mallala. This pick-up point was transferred to Edinburgh Airfield in August 1954.

Although hardly luxurious by modern standards, the new Bristols were vastly better than the Dakotas. Their main drawbacks were the engine din which filled the cabin and the draught caused by the poor sealing of the nose petals. Nevertheless they were real workhorses. Freight items as large as a truck could be loaded directly through the petals of the bulbous nose. They could each carry thirty-six passengers and a little freight, or no passengers and up to 3.7 tonnes of freight, or something in between. By 1953 the three Bristol Freighters were regularly transporting into and out of Woomera each month over 1000 passengers and 50 tonnes of freight—varying from milk and eggs to advanced electronics.

There was much more to the Woomera airlift than the regular courier service. No. 34 Squadron was also there to provide special passenger and freight flights, often at short notice, and often to other airfields and to the airstrips of pastoral stations in the Range area. The Viking was reserved for VIP work, but the two Avro Mk 19 aircraft were used as much as their small number and size would allow. Not all flights were on strict joint project business. In March 1948, only a few months after the Avros arrived, Flight Lieutenant Lee Archer flew one of them on a mercy flight to Mt Eba to rescue a passenger severely injured in a crash of a Hawk Moth. He returned to Parafield in the night, and the prompt medical attention undoubtedly saved a life.

In September 1951 a fourth Bristol Freighter was added to the fleet of three, to handle the increasing load of passengers and freight on the courier service. Before then it was rare for all three to be available, as each Bristol had a major overhaul every twelve or eighteen months, and it often took six months or so. The service continued smoothly until 25 November 1953. During a routine training flight a wing came off a Bristol and it crashed into a wheatfield near Mallala, killing all three of the crew.[13] The remaining three Bristols were immediately grounded and it was back to the side saddle Dakotas until January 1954, when a RAAF court of inquiry found the crash had been due to abnormal flying during

The Bristol Freighters replaced the Dakotas and became the workhorse of the RAAF airlift.

training and cleared the aircraft for routine flights. The courier service resumed, although a few passengers preferred to take the slow and infrequent train.

The Bristol crash forced a reconsideration of the Woomera airlift. To continue the service as before the RAAF would have to buy a replacement Bristol, and because the Sandys Agreement had been in force since September 1953 Australia would be paying. One alternative was to charter aircraft regularly, which was sometimes done for special flights even before the crash. It could be cheaper if all the hidden costs of the RAAF courier service were taken into account. Eventually the charter proposal won, not only on economic grounds but because the RAAF had other commitments and was short of manpower—it wanted to transfer elsewhere some of the airmen now flying and maintaining the Bristols.[14] Another factor in the decision may have been that passenger numbers would probably be increasing in the future.

The regular charter service started about October 1955, operated by the South Australian intrastate airline, Guinea Airways (which became Airlines of South Australia in December 1959 and Ansett Airlines of South Australia from August 1968). For some years Guinea had operated a bi-weekly service to Woomera for private passengers and freight, which the RAAF could not carry.[15] Initially there was a daily flight by a DC-4 Skymaster, supplemented on the busy Monday up and Friday return service by three DC-3 flights. In July 1958 the DC-4 was replaced by a Convair 240 and later a Convair 440, which served until Fokker Friendships were introduced. The service continued, with remarkable regularity, reliability and freedom from accidents until it became uneconomical with the run-down of the mid-1970s. The last flight of the Ansett service was on 20 April 1979. It was taken over by Opal Airlines as part of their scheduled services to Olympic Dam and Andamooka.

This was not the end of the RAAF Bristol Freighter service. Supplemented by two or three Dakotas, the three remaining Bristols continued to fly a reduced regular freight-only service to Woomera, normally carrying items too large or too heavy or too secret for the charter service, together with passenger and freight runs both regular and special to airfields like Giles and Talgarno that were not fitted for civil airlines. They also ferried Pika and Jindivik aircraft to Woomera, as well as the Australian missiles Malkara and Ikara from Laverton and Fisherman's Bend in Victoria. The Bristols went on flying until June 1967 when, after eighteen years' service, they were withdrawn for disposal.

Despite the 1953 crash and maintenance problems from time to time, the ungainly Bristol Freighter was perhaps the wisest choice of aircraft made during the project. The Viking was not as successful. This was a VIP version of Britain's first post-war airliner, originally designed to carry twenty-four to twenty-seven passengers on the short European routes. LRWE's single Viking could carry twenty passengers in VIP comfort but in fact rarely carried more than eight. It was hard to justify its use for small loads, so it spent most of its time on the ground—an expensive luxury. In the early years it could have replaced one of the Dakotas on the Woomera service; but then it would not have been available for the occasional VIP flight. Luxury for a few VIPs then had higher priority than reasonable comfort for the many. The Viking lacked the capacity and versatility of the Bristol Freighter, and when the fourth Bristol arrived in October 1951 the Viking went back to England.[16]

As a replacement for the Viking a specification was drawn up in 1950 for a twin engined 'medium sized aircraft'.[17] It was to carry eight to twelve VIPs with their luggage, or six passengers plus freight and luggage. Interior furnishings had to be easily removable to carry freight or stretchers, and it had to be suitable also for aerial surveying and photography. Its prime role, though, was VIP transport and a high wing monoplane was specified so that everyone could have a clear view of the ground.

After surveying what British medium sized aircraft were available, the tentative choice fell on the Percival Prince. Although the Board asked London if there was not something more suitable, it subsequently resisted British pressure to take the more common four-engined 22-passenger Miles Marathon, feeling that like the Viking the Marathon was too big for the purpose. So in the end London agreed to substitute three 10-passenger versions of the Prince for the Viking and two Ansons.

The three new aircraft were delivered between March and June 1952, the first two by RAAF crews and the last by the RAF. They were only fitted for eight passengers, as it had been reluctantly agreed to take out two seats to save weight and give it the 950 kilometre specified range. The following December the RAAF reported that when some '[minor] troubles are cleared and the squadron obtains some operating experience the Prince will be a very useful and rugged light transport'.[18] The prediction proved wide of the mark. In May 1953 the Air Requirements Committee (ARC) of the Board was asked to look at the Prince as 'this aircraft does not meet the figures contained in the brochure published by Percivals'.[19] Test flying on only one engine had revealed dangerously high temperatures and low pressures in the oil system. Another kind of complaint came from Prime Minister Menzies himself who, with characteristic vigour, described the Prince as 'a flying ironworks, a machine in which you can hardly hear yourself think, a machine in which you can see the wheels go round'.[20] The ARC supported these complaints, quoting RAAF tests which showed that if regulations for VIP carriage were enforced only four should be carried on mild days and just *one* on the hot days of 40 degrees which are far from rare during the Woomera summer. When the RAAF's Aircraft Research and Development Unit (ARDU) completed its tests at the end of 1953, the conclusion was that the Prince should carry only two to five non-VIP passengers between Parafield and Woomera, depending on temperature and weather.

The Princes went on being used for another eighteen months, under the restrictions recommended by ARDU, but their end was ignominious. On 28 January 1955 one of them was damaged when the undercarriage collapsed on landing at Edinburgh. Butement did not hear about it until the following June when the Department of Air asked him for approval to write it off, and he was displeased not so much about losing the aircraft as about not being told. 'I am amazed to find', he teletyped to WRE Controller H. J. Brown, 'that one of our aircraft can crash without this office receiving immediate advice'.[21] Brown had to report the accident belatedly. He had to add that a second Prince had been damaged only a fortnight before; it too would probably be a write-off. The only remaining Prince had been grounded.

Despite some attempts, official and unofficial, to get MoS to replace the ill-starred Princes, the whole question of VIP transport was apparently shelved without being resolved. Once the charter service was well established, special charters could be arranged at quite short notice and eventually it became possible for Melbourne visitors to pay a visit to Woomera in one day (Wednesday), although they had to stay in Adelaide the previous night. And there was always the RAAF VIP Flight based at Fairbairn, ACT, for the most exalted visitors. Thus the problem of VIP aircraft that the ARC and the Board agonised over for some years was never really solved—it simply went away.

For the more mundane work of transporting small groups of non-VIP passengers, two single engined DHC-3 Otter aircraft made by De Havilland Canada were acquired in 1962.[22] The two Otters were based at Woomera and used mainly to establish a Range Air Ferry Service, so that the new down-range instrumentation sites such as Mirikata and the two 'forty mile' Contraves posts could be manned for regular early morning trials: the operators commuted daily between Woomera airfield and airstrips at these sites.

One of three Percival Prince aircraft used by the project, following its accident in January 1955. It was written off.

A French built Alouette III helicopter picking up passengers from the treacherous surface of a dry salt lake in the range area. The Alouette displays civilian markings as by then (1968) Short Bros & Harland Air Services had taken over from the RAAF.

While the Bristol Freighters, the Viking, the Dakotas and Ansons and Princes had all been based originally at Mallala, the Otters and a number of smaller utility aircraft lived at Woomera, and were flown by ARDU Trials Flight and its successors. Of these aircraft types the smallest was the single engined Auster Mk 3, the first aircraft to be based at Woomera (August 1947). It was used for reconnaissance, missile round recovery, spotting and other work. Early in 1956 two Winjeel aircraft replaced the Austers and were successfully used for Range communications duties carrying up to two passengers at a time, as well as for round recovery and reconnaissance work. In 1951 the first helicopter, a Bristol Sycamore, appeared at Woomera and proved most useful for missile recovery.

The final utility aircraft acquisition was three French-built Alouette III helicopters in 1964. As each could carry up to six passengers, they replaced both the Winjeels and the Bristol helicopter, and were used to extend the Air Ferry Service; small helipads were constructed at various Range posts. When the RAAF withdrew from Woomera in 1967 and retired the three Bristol Freighters, the Otters and the Alouettes became the last survivors of the airlift.[23] A civil contractor, Short Bros & Harland Air Services took over flying them at Woomera until the final stages of the Woomera run-down; they were withdrawn in 1979 and disposed of late in 1980, just after the project ended.

TRIALS FLYING

The flying of aircraft for trials began only five months after the Mallala base was established. In October 1947 an Experimental Flight Unit was formed at Point Cook, Victoria as part of the RAAF Aircraft Research and Development Unit (ARDU)—a unit that nearly thirty years later was to move to the Salisbury area. The following month this unit moved to Mallala and almost at once began flying an Australian-built Lincoln bomber to drop parachutes in the historic first ever Woomera trials campaign. However, for the first eight years of the joint project the main task of Experimental Flight was to fly Lincoln bombers to the bomb ballistics range, the earliest Woomera range to be built, and there drop bombs of various shapes and sizes. Other bombs fitted with proximity fuzes were dropped on a separate range. In August 1950 the Flight moved its base to Woomera to be closer to these ranges, and at the same time changed its name to ARDU Trials Flight. The story of the part played by ARDU in these air trials is told in Chapter 10.

Trials aircraft of the RAAF Aircraft Research and Development Unit (ARDU), lined up on the tarmac at Woomera in 1953.

Dropping bombs was not all that Trials Flight had to do. A section was set up at Evetts Field in 1952 to operate the Jindivik target aircraft, and later the pilotless Meteors and Canberras as well. Trials Flight also flew aircraft in countless other trials at Woomera, including the RTV1 recovery trials and various instrumentation trials and checkouts. Sometimes WRE civilian observers also flew in these trials aircraft. The RAAF aircrew were not always enthusiastic about civilian observers. Veteran optical technician Ron Nicholson recalls that in 1957 he was involved in preparing the prototype of the Wretar target camera for flight tests in a two seater Meteor Mk 7. His chief, Bob Bonnell, was not happy with the results so he asked Nicholson to fly as an observer, and arranged it with a very reluctant RAAF. On the appointed day Nicholson was a little puzzled that he could see none of the normal RAAF crew with whom he was on friendly terms:

Anyway I was very thrilled. The Squadron Leader himself seemed to take an interest in me and lent me his own oxygen mask. We were to fly over markers on the airstrip at 40 feet altitude and then go up to 70 feet, flat out. Away we went and the pilot says: 'Oh, I'll have to practise a bit, I don't know this airstrip very well', so he dived down on to the strip, shot across these markers, and up he went again. He said: 'Yes, I'll have to practise a fair bit, that wasn't too good. How are you feeling?'

'Ooh, I'm fine. Very enjoyable', I said.

'Oh well, I think we'd better go up higher and then perhaps we ought to approach the target upside down and get a better look at it that way'. So we went up to some altitude, I don't know what it was now, and we rolled over; and as we rolled over I thought I was going to fall out of the cockpit. But my harness suddenly took up the slack and I was quite safe as we came down into the dive. We did this many, many times and eventually I was sick. Then the humiliating moment came. His voice came over, sharp and clear: 'Mission accomplished, crew sick, permission to land?' I learned afterwards that the harness had been deliberately left loose and as for the oxygen mask, someone had vomited in that a few days previously.[24]

RAAF pilot Squadron Leader H. V. Shearn.

Incidents like this were atypical because working relationships between the RAAF and WRE were usually friendly. But RAAF pilots were responsible for the safety of their aircraft and the rules discouraged carrying civilians in aircraft, particularly jets, which were designed for trained aircrew only. Nevertheless the rules were sometimes bent, as with the early parachute drops and the paravane tow target trials for RTV1 recovery.[25]

Manned aircraft were also used in Woomera trials to launch air-to-air weapons such as Blue Sky, Blue Jay and Red Top. Most of them were flown not by the RAAF but by RAF, Royal Navy or civilian test pilots sent out from Britain for specific trials. However, during the Blue Jay R&D trials from 1955 to 1958, all the missiles were launched from specially fitted RAAF Sabre and UK Canberra aircraft. RAAF pilot Squadron Leader H. V. Shearn of ARDU fired most of them, and he shot down the first Jindivik destroyed over Range E.

Trials flying was to go on to the end of the project and beyond. Its main base, however, gradually shifted from Woomera southwards in the late 1950s—not back to Mallala but to the new airfield next to Salisbury.

MOVING TO EDINBURGH—AND REORGANISING

With Edinburgh Airfield officially opened in March 1954 but not quite finished, the Air component took a little time to move into its new home. No. 34 Squadron remained at Mallala and ARDU Trials Flight stayed at Woomera for the time being. However, in October 1954 a small detachment of Trials Flight was set up at Edinburgh, which was to be the base for aircraft fitted with the air-to-air missile Blue Jay, soon to be tested at Woomera.

Group Captain Peter Jeffrey.

With the creation of WRE in January 1955 the Air component of LRWE disappeared altogether. In its place Headquarters RAAF Edinburgh was formed as a separate unit under direct RAAF command, and its Officer Commanding, Group Captain Peter Jeffrey, was in charge of all RAAF elements at Woomera and Mallala as well as Edinburgh—a total strength of 534 at the end of 1955. The Trials Flight, now separated from its parent body ARDU, was renamed Air Trials Unit (ATU). It had been intended to move 34 Squadron to Edinburgh during the year, but instead it was disbanded altogether in October after handing over its flying duties and custody of its Bristol Freighters and Dakotas to an enlarged Edinburgh detachment of the ATU (now known as Detachment A). Thus ATU now operated all WRE aircraft.

Despite the reorganisation, Edinburgh was still very much a joint project air base. The project still owned it, all the elements under the control of OC RAAF Edinburgh were committed to joint project work, and project funds maintained it. The main change was that it was now all integrated into one RAAF organisation under direct RAAF control. The old Air component of LRWE was a loose grouping of detached RAAF units, nominally under the control of a superintendent with no staff and no real command. The last occupant, Group Captain Jeffrey, even had to rely on unofficial advice from an old RAF friend attached to one of the units to find out what was going on. To this was added confused and uncertain loyalties, because of the dual titles of senior officers in the component which reflected their RAAF and LRWE roles.[26]

During the next five years or so the pace of life quickened at Edinburgh. The Bristols were no longer carrying passengers to Woomera, but there was plenty of freight work and special passenger flights for them to do. The regular charter passenger service from West Beach to Woomera used Edinburgh to pick up WRE passengers on the afternoon flights, and the RAAF Base Squadron ran the Air Transport Office at Edinburgh. British servicemen from all three services were stationed there from 1955, attached to the various Joint Services Trials Units (JSTUs) that carried out the acceptance trials of guided missiles at Woomera. When the Maralinga range was established in 1956 Edinburgh became one of its supply bases. But most of the rise in tempo came from trials flying: increasingly, the bomber and fighter aircraft that dropped bombs or fired missiles on the Range took off from Edinburgh rather than from Woomera airfield.[27] This was a reversal of policy, for ARDU had originally moved its Experimental Flight from Mallala to Woomera so that the lumbering Lincoln bombers could take off with less fuel and thus fly higher. This ceased to be a problem with the Canberras, Valiants and other bombers that replaced the Lincolns, and Edinburgh offered cheaper and more plentiful accommodation and better technical facilities. In 1955, ATU Detachment A at Edinburgh had been solely concerned with air transport but now it was more and more a trials flying unit. This led to a further reorganisation. After 31 March 1958 ATU split into two—No. 1 ATU at Woomera and No. 2 ATU at Edinburgh—both under the direct command of OC RAAF Edinburgh.

By the mid-1960s both trials flying and the need for air transport was waning, and in April 1965 the RAAF told WRE that it wanted to reduce its joint project commitments. It pulled out of Woomera altogether in September 1967, after handing over to a private contractor (Short Bros & Harland Air Services) the only work left for them to do—running the Range Ferry and Recovery Flight and the Jindivik and Meteor target service. By now Edinburgh was being used more and more for RAAF work not connected with the joint project. No. 1 Recruit Training Unit was posted there in May 1964 to give basic training to all new enlistments. No. 24 (City of Adelaide) Squadron[28]—part of the Citizen Air Force—had already shifted to Edinburgh after the RAAF base at Mallala finally closed in May 1960. Then in February 1968 the final act came. With the transfer of No. 1 Squadron from Richmond, New South Wales to Edinburgh, closely followed by delivery of its new P-3B Orion maritime surveillance aircraft, the airfield was no longer a joint project but an RAAF base. Ownership was formally handed over from the Department of Supply to the Department of Air, with control from HQ Operational Command. Britain relinquished its share (estimated to be worth £lm sterling) for nothing, although this was offset by immediate savings on its share of the costs of support flying.

For a while Edinburgh continued to support the project in a minor way. No. 2 ATU continued until February 1970 when ARDU Laverton took over the remaining trials flying (in December 1976 ARDU itself was to transfer to Salisbury and use Edinburgh as the base for its aircraft, although its HQ was set up in the Contractors' Area).

Thus it came about that, despite the delays and confusion of its origins, the project's centre of air operations escaped the fate of being run down like the Range itself. It is now a major RAAF base. Yet it was the joint project that built Edinburgh from an abandoned wartime cordite factory and some adjacent farmland. To that extent Edinburgh is one of its lasting fruits.

An RAAF Lockheed Orion P3B in flight. These maritime surveillance aircraft were based at Edinburgh from 1968 until replaced by P3C.

LINKING THE PARTNERS

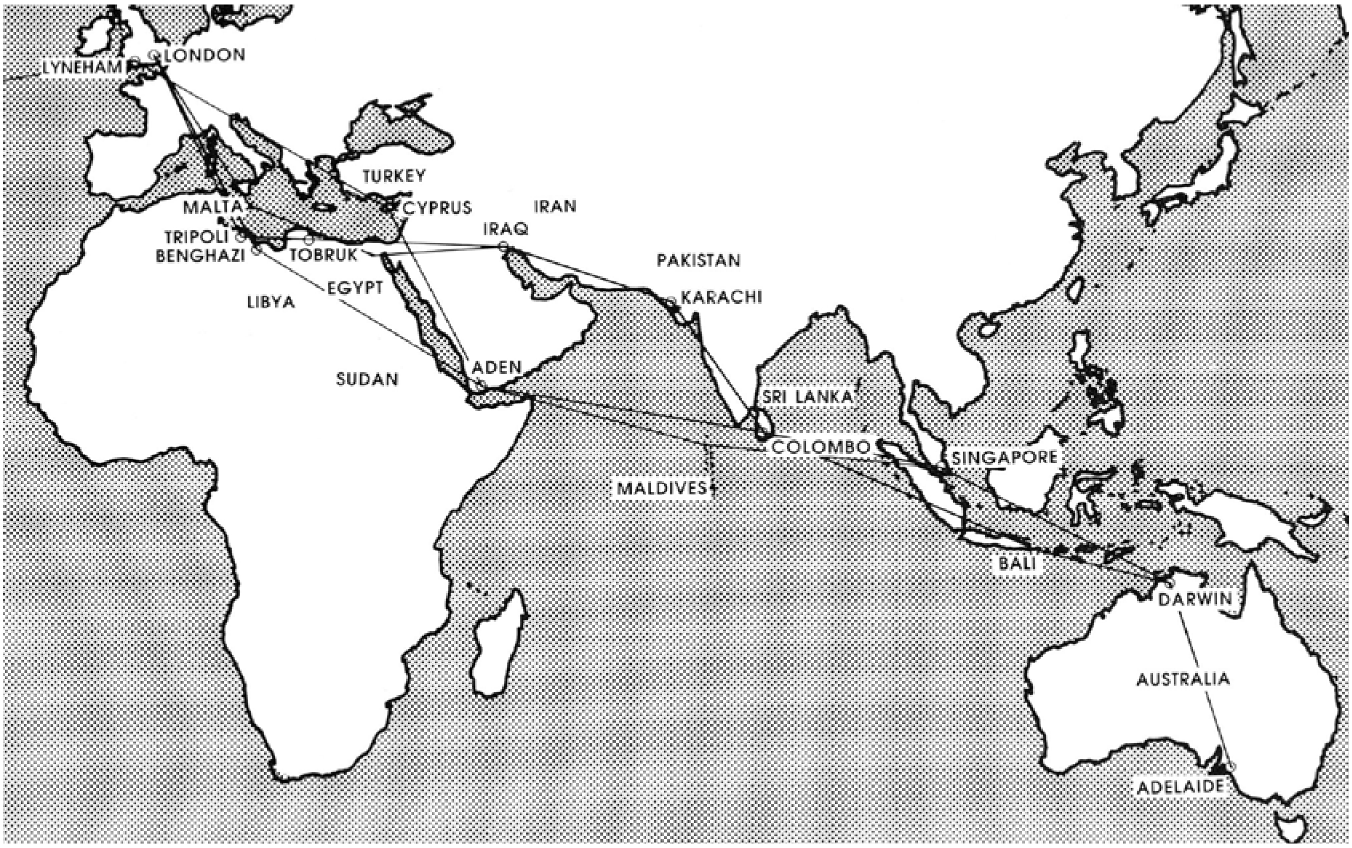
No less than good domestic communications, good international communications were vital to the success of the joint project. With the partners a world apart, their collaboration would have been impossible if information, cargo and staff could not have been transported quickly and reliably across the 19 000 kilometres which separated them.

In the first years after the war, the only air route between Australia and Britain was operated by a Qantas/BOAC scheduled commercial air service. It took the traveller several days to get from Sydney to London, as he traced his leisurely and expensive course via Darwin, Jakarta, Singapore, Calcutta, Karachi, Beirut, and Zurich or Rome. At first, for the most urgent visits, joint project staff used this service in conjunction with the internal airlines TAA or ANA to get themselves to Adelaide. Men with families coming to take up permanent posts at Woomera or Salisbury usually travelled by ocean liner, arriving at Port Adelaide. Cargo went by sea and then by road to Woomera or else was air-freighted in Avro Yorks, which had originally been passenger planes designed around some Lancaster bomber parts. Later on, special arrangements were made for difficult cargoes. For example, the British charter company Dan-Air contracted to deliver the first Black Knight rocket to Woomera. They used a Bristol Freighter which, with its front end loading, was the only plane capable of taking the length of the rocket in its packing case. The heavy load reduced the Bristol's modest range even further, and the chosen route with its eighteen stopovers closely followed the pioneering flight of the Smith brothers from England to Australia. On reaching Darwin the Bristol continued to Woomera, making three further refuelling stops on its flight across the Centre. The first five Black Knights were delivered by Dan-Air using the same aircraft and the same four man crew. The flight took eight days and was only once delayed by engine trouble.

But between 1952 and 1975—for most of the project, in fact—the British Ministry of Supply ran a regular courier service between (at first) Lyneham in Wiltshire and Mallala. This operation, which made use of various military and civilian transport organisations, came about at the urging of Chief Superintendent Harry Pritchard and Bill Boswell (then the Superintendent R&D), at a time when both were at Woomera. As Pritchard remembers it:

> A visit to Woomera was 'the thing to do' for all VIP visitors from UK, whether senior service officers, captains of industry or members of government, and each usually spent a night at Woomera. After a few hours touring the area and then being wined and dined, the visitor often became our 'captive victim' for the evening—Bill Boswell, a man of initiative but with an eye for practical results, and I used to spend an evening over a beer or two before each visitation, to consider how the visitor might be able to help the project. We had some successes—for example, transport to and from UK was a problem, because some stores could not be sent on civil aircraft due to safety regulations, and when we wished to send a scientist to visit UK it was expensive. . . . With the visit of a very senior RAF officer [Air Marshal Coryton] we suggested that UK Transport Command should run a ferry service to Australia, arguing that it would be good training for Transport Command personnel as well as help us.[29]

The result of these earnest representations was that for five years up to 1957 the RAF Transport Command (TC) provided a regular fortnightly service for both freight and passengers, plus some extra flights for freight only and explosive cargoes (the latter generally landed at Woomera). The aircraft were Handley Page Hastings with four piston engines, planes often dubbed the safest in the world with an engine out of action, and much used by the RAF for carrying paratroops, towing gliders and generally moving people and freight around. On the Australian run its capacity was four tonnes of freight or twenty-eight 'pax' (as passengers were known) with their luggage, or a combination of the two; a common load was twelve pax at the rear with freight filling the forward portion of the fuselage. The seats faced towards the rear, as the Ministry insisted they should.[30] The Hastings was of course painfully slow by modern jetliner standards and so noisy that conversation was next to impossible. The top cruising speed was only 320 kph with a flying time of around 12 hours. The cabin was not pressurised and when the plane rose above 14 000 feet, which it did infrequently, the passengers had to don oxygen masks. The crew were six: a pilot, co-pilot, engineer, navigator, wireless operator, and quartermaster. These RAF quartermasters were terrific characters, old sweats who had spent a lifetime in the service, and many a passenger found relief from a boring 80 hours in the air without tobacco or alcohol listening to their great fund of stories and watching their dealings. For the quartermaster was a free trader in a global market. On the trip out from England he would bring on board a vast



suitcase which served as his shop. His first stock was the excellent Marks and Spencer's goods: ladies' underwear, nylons, shoes, men's shirts—anything likely to bring a profit in the drab post-war world, although as a rule he did not deal in alcohol, cigarettes or contraband. At each overnight stop these goods were disposed of according to orders taken on a previous flight. Not all the transactions were cash. In Ceylon, for instance, the white St Michael business shirt was a premium item and could be bartered for a surprising quantity of jewellery or unmounted gemstones which could in turn be traded further down the line. As the quartermaster's stock diminished he replaced it with local manufactures: crocodile skin handbags, watches, brocades, perfumes and so on. Towards the end of the return trip the suitcase would be empty, its contents transformed into a wad of cash, all exchanged out of a dozen different currencies into sterling. It could not, of course, be declared at Lyneham. The last trick at the final stopover before England was to drop the lot into a 'Forces' Mail' letterbox in a self-addressed envelope.

The quartermaster's official duty was to look after the passengers' creature comforts. In practice this meant little more than dispensing to each one a cardboard box of food to last over that day's flight, and that box typically contained a soggy piece of lettuce, a dried up chicken leg and a hard boiled egg. On provisions like these the trip certainly felt as if it were taking every moment of its seven tedious flying days, but it did have the compensation

Top right: A Handley Page Hastings aircraft on the tarmac at Edinburgh during its inaugural courier flight.

Top left: The rearward facing passenger seats on the Hastings. Freight was stowed in the same area. Note the flight rations in the lower left-hand corner.

Typical routes of the courier service. Stops varied, often because of changing local politics that each night was spent tucked up in the comfortable billets of the RAF stations along the route. In these little outposts of a fading Empire one could combine the familiar with the exotic: it was egg and chips for dinner in the mess, but at Mauripur one could use the 'flying dhobi' laundry service offered by 'an enterprising native servant'. The leisurely trip was stretched out even further by a stopover in Singapore for a day or two; but even so barely half the flights met their schedules. Delays ranged from a few hours to weeks, and the passengers' reactions depended largely on where the enforced stops were. The possibilities were large, for the various routings included airfields at Malta, Tripoli, Benghazi, Tobruk and then (depending on the political situation) either through the Middle East via Cyprus, Turkey, Iran and Pakistan, or more to the south via Libya, the Sudan and Aden. The final leg was Ceylon, Singapore (occasionally Bali), Darwin and South Australia.

The long trip gave many a young man his first experience of foreign life, and he could read up about it first in an appealingly written Ministry of Supply handbook full of canny advice. He was advised to take in his hand luggage a brandy flask and spare studs and links for his shirt cuffs; informed that 'it is generally possible to secure a good seat by walking briskly but inconspicuously, and getting to the aircraft first'; and warned that 'the Customs Officer at Lyneham has had to remind passengers that Brandy is not a Table Wine'.[31] The courier service was sometimes used for other than joint project personnel. One was a young officer taking up a post as Equerry to the Governor of South Australia. During the overnight stop at the RAF base of Habbaniya in the Iraqi desert he made up a party to visit Baghdad, 100 kilometres away by truck. They spent the last part of the evening in a fairly refined night club. In the Middle East such clubs are strait-laced in their manners even when, as here, the star attraction was an exotic dancer clad only in a coat of gold paint. At the end of her performance she made her exit through the audience, exposing a shapely rump close to the Equerry who, carried away by the oriental atmosphere, bent to kiss or nip it. The result was a large golden ring on his face and an echoing scream from the girl. Fortunately a big resourceful Wing Commander, a member of a wartime cloak-and-dagger brigade, knew what to do. He had a five pound note on the table and the Equerry back in the truck before anyone had time to react to the insult.

Sometimes the long flying hours might be enlivened by practical jokes. One favourite required a young army private, preferably one nervous about his first flight, to be induced to take a rear seat next to the toilet, facing forward. Well into the flight the cabin door would pop open and the pilot would slowly emerge, shuffling backwards towards the toilet. With fascinated alarm the soldier would note that as the pilot edged down the aisle he was paying out two taut cords, both of them vanishing into the cockpit. As the plane bucked and swayed he would tug gently on these reins, his tightly compressed lips suggesting he was barely holding his unruly steed to its course. The lines and the nerves of the watcher would stretch out unbearably until the pilot at last reached the rear and his goal. Here on the

toilet's threshold he would kick open the door and jig about, acting the part of one suffering from acute distension of the bladder and jiggling the reins until the soldier was white with terror. Then at the psychological moment he would gasp out a desperate instruction, slip the cords into the nerveless hands of the victim and disappear inside. Immediately the plane would misbehave very badly indeed. The hero, now frozen faced and feet braced wide apart, would find he could only stop it toppling out of the sky by the most desperately cautious of twitches. Sometimes his anguish could be stretched out for several minutes until the stifled laughter of the other pax burst forth and gave the game away.

Except by design the Hastings rarely misbehaved. In its five years of courier service only a handful of incidents sullied its record for offering an extremely safe, if hardly punctual, service. One Hastings was 'lost' for a few days after making an emergency diversion to Denpasar in Bali while en route to Australia. In September 1955 a much more terrifying episode involved a Hastings with eight passengers cruising above the Indian Ocean at 10 000 feet half-way between Karachi and Sri Lanka. Suddenly there was an awful shriek of tortured metal and the passengers saw the propeller on the inward starboard engine tear itself free, go skimming across the wing and begin its long fall to the sea below. Into the tailplane crashed more bits of engine, which was then enveloped in flame. Fortunately the pilot was able to maintain height, throttle back and get the fire-fighting system working. His Mayday call was received by Bombay, which arranged for an emergency landing at the Cochin Naval Base on the tip of India. The pilot made a perfect touchdown despite the fact that the plane was far too heavy for the runway; indeed, the wheels began to sink into it after everyone had disembarked. Now the thankful passengers had one more hurdle to surmount. One of their number recalls:

> The senior naval officer explained quite apologetically that we had better do the right thing and fill up a customs declaration form. He had sent for a Customs man who arrived shortly on a very worn out old bicycle with a large bag perched precariously on the handlebars. He then produced a form for each of us to fill in. It was the largest declaration form we had ever seen and contained 100 or more questions. The early questions were in quite large print and the size of the print gradually diminished as the questions proceeded. The questions were straightforward enough, simply requiring a 'yes' or no' to each one. The first question, in very large print, was 'Have you in your possession a grand piano?' Although this inquiry was received with some hilarity it still had a certain logic: presumably if everyone entering Cochin came with a grand piano, the place would soon be choc-a-bloc with pianos.[32]

After this unnerving start the Indian naval people made them very welcome and they stayed a week, jaunting round the island in a launch. When they finally arrived in Australia they had been in transit for a record month.

For three years (1957-60) Transport Command switched to the Comet II jet, which was able to take twenty passengers on its fortnightly trips or even up to thirty-six in peak periods. The De Havilland Comet was a remarkable plane for its day. It was fast and could cover the route in only two days with a day and a night stop in Singapore. The route was Edinburgh RAAF base next to Salisbury, Darwin, Singapore, Gan in the Maldive Islands, Aden, Cyprus and finally Lyneham. If the stopover were eliminated, the journey could be done in about twenty-four hours of flying, a remarkable feat. Travelling west from Singapore at 800 kilometres per hour after breakfasting on porridge, eggs and bacon in the RAF mess,

A RAF Comet II jet transport aircraft, used 1957-60.

one could land in the Maldives just in time for the same fare and then fly on to Aden in time to enjoy it all over again. The first Comet, being prone to a mysterious structural failure, had killed nearly a hundred passengers, and the Comet II used by Transport Command had been modified to rectify these problems. Before the first of these Comet flights a RAF officer gave a long and sombre lecture on the safety and ditching procedures. The faces of the pax gradually took on the tense expressions of a bomber crew being briefed for a night sortie over Berlin.

The Comet could only take mail and small items of cargo, for it had no wide freight doors. Big freight continued to go by Hastings, supported by six Avro Traders belonging to Air Charter Ltd owned by Freddie Laker—the ebullient businessman later famous for his cheap charter operations. In 1959 Laker replaced the Traders with Douglas DC-4s. The withdrawal was hastened by the loss of two aircraft on their way to Adelaide early in that year. One crashed on landing at Brindisi and burnt out, and the other crashed into a mountain in Turkey.

In June 1960 Air Charter merged with several British independent airlines to form British United Airlines (BUA), still under the control of Laker. BUA took over the contract held by Air Charter. From August 1961 the erstwhile courier service became a charter service with the letting of a new contract to BUA. This operated Douglas DC-6s and ran this time from Southend to Adelaide Airport. Though the flight time increased to four days with three night stops, everyone appreciated the commercial standard service and the proper food. There were very few delays in flights. Within two years booming business at Woomera saw a great increase in passenger traffic and BUA introduced Britannia aircraft for passengers, mail and small freight, continuing with the DC-6 for larger freight. In 1962 BUA lost the contract to Cunard Eagle Airways. Initially Cunard Eagle used DC-6s for three services a week, but the following year the company's name changed to British Eagle and soon after Britannias were introduced to the route. It was British Eagle's owner-director Harold Bamberg who conceived the idea of putting a larger door into the Britannia enabling it to take large freight. These aircraft were quite comfortable and very reliable, with the service more like first class on a commercial flight. One of these modified Britannias, called Charlie Fox after its registration, G-ANCF, was not new when bought by British Eagle from an Argentinian airline, but it became legendary as the longest serving aircraft on the courier service which it flew for more than a decade. British Eagle continued flying to Adelaide until 1968, when the airline ceased operating due to financial problems. A new company, Monarch Airlines of Luton, took over using the same Britannias. In its service with Monarch, G-ANCF was painted bright yellow and nicknamed The Flying Banana. The routes used became varied and even included some flights via Brisbane, Fiji, Hawaii, San Francisco and Newfoundland. The frequency of the service was usually fortnightly, but it altered with demand and in the busiest years of the project ran two flights a week into Heathrow. The last flight out of Adelaide was in December 1975, and for the remaining few years after that people used the RAF Transport Command VC-10 service from Britain to Hong Kong and commercial flights.

Notes and Sources

1. Wackett was the longest serving of the services representatives on these bodies. His term lasted from the first meeting of the GP Committee in April 1946 until he retired from the RAAF in December 1957.
2. The LRW Organisation was founded on 1 April 1947. Edinburgh Airfield was officially opened on 22 March 1954.
3. Gardner may not have originated this idea. S. A. Hunwicks recalled that he raised it several times with the head of the Salisbury establishment, A. P. Rowe, who opposed it because of airfield noise problems, and possibly also because he was accustomed to a separation between his old establishment of TRE Malvern and its RAF support airfield at Defford. Rowe departed just before Gardner's visit in July 1947.
4. To avoid interference a controlled zone was set up for Edinburgh with boundaries such as the Little Para River, which is lined with trees and easily visible from the air.
5. There were later problems with dust from the 'grassed' runway during the dry 1962-63 summer, and moves to pave it or to install a watering system.
6. 'New Aerodrome', The *Herald* (Melbourne), 4 May 1951.
7. Teletype SAM957 of 26 January 1954. File SA5050/2.

8. 'Duke's first speech here lasts 6 sec', The News (Adelaide), 22 March 1954.
9. Reminiscence of Dr H. J. Brown at an interview of 9 July 1985.
10. Reminiscence of Miss Ailsa MacDonald at an interview of 27 January 1984. There is another story that the Duke had only just heard that the name 'Edinburgh' was to be used and had not in fact given his assent.
11. MacDonald interview. Miss MacDonald claims and Brown confirms that it was the Range Superintendent Group Captain A. G. Pither who fell into the trap and never forgot it.
12. N.H. Fresson, one of the original Evetts eleven, recalls that he and Butement had to put in a bid for project aircraft in 1946, before departing for Australia. At that time Britain's first post-war generation of aircraft was barely in production, but nevertheless they studied the specifications and drew up a short list, which included the Bristol Freighter and the Viking. They then persuaded Air Marshal Coryton, who was Controller of Supplies (Air) in MoS at the time, that the new Australian range would make a good shop window for British aircraft, and he agreed to let them have any of the aircraft on their list that were assessed as suitable. Fresson adds that on the arrival of the eleven in Australia the Chifley government sought to present the project with war surplus Dakotas, in order to justify equipping the new national airline TAA with brand new American aircraft on the grounds that all the Dakotas were needed for the Range. For a while hopes of using the Bristols and other new British aircraft faded away, but under the prevailing joint project agreement Britain supplied the aircraft and the Australian move failed. Communications from Air Commodore N. H. Fresson in 1982 and 7 January 1986.
13. 'Three die in Mallala air crash', *Advertiser*, 26 November 1953.
14. Letter of 10 June 1955 from Secretary, Department of Air to Secretary Department of Supply. Copy on file SA5030 part 3.
15. This was no longer a problem with the charter service. Although the Department paid a flat rate for each flight, Guinea could take private passengers and freight on certain off-peak flights (normally charging full rates) and credit the Department with the proceeds.
16. In one view, LRWE by handing back the Viking 'was looking a gift horse in the mouth: rather like dispensing with the gift of a Rolls-Royce and then buying a Ford Escort just to save petrol'. Fresson communication of 7 January 1986.
17. Attachment B to Agenda for 32nd meeting of Air Requirements Committee, 15 May 1953. File SA5030.
18. 'This squadron serves the Rocket Range', *Aircraft*, December 1952.
19. Minutes of 23rd meeting of the Air Requirements Committee held 1 May 1950. File SA5030 part 1.
20. 'Plane was too small for PM', *The Mail*, 2 May 1953.
21. Teletype MSA7356 dated 21 June 1955. File SA5030 part 3. Peter Jeffrey, who was then OIC at Edinburgh, recalls that he had reported the accident to the Department of Air, and had told Brown's deputy Boswell. Apparently the message did not get through. Jeffrey was asked to report accidents affecting WRE direct to the Controller in future.
22. A smaller Beaver aircraft was chartered from De Havillands as an interim aircraft from 1959 until the two Otters were delivered in 1962.
23. However, the RAAF No. 2 ATU continued to fly Dakotas from Edinburgh until 1969.
24. Anecdote of Ron Nicholson at an interview of 22 August 1985.
25. Comment from Wing Commander H. V. Shearn, OC Flying in No. 1 Air Trials Unit at the time.
26. Thus the OC of the old ARDU Trials Flight had been responsible in the RAAF hierarchy to the CO of ARDU Laverton, but in the LRWE hierarchy he was 'Principal Officer Flying' responsible to 'Superintendent Air' at Salisbury, and he also acted as air adviser to the Range Superintendent at Woomera where he was based.
27. The first trials aircraft based at Edinburgh were two Boeing Washingtons that had been used for Red Rapier trials. They were flown from Woomera in October 1954.
28. 'WRE's own Squadron', *Missile*, March-May 1975. At the time nineteen WRE officers spent three weekends in seven as members of the fifty-two strong No. 24 Squadron.
29. Quoted from an undated contribution (c. 1977) from H. C. Pritchard.
30. The greater safety of rearward facing seats has been well established by both the RAF and the USAF, but no commercial airline has dared to introduce them because of the effect on public confidence.
31. Quoted from *Air-travel Arrangements from UK to RAAF Station, Mallala (for LRWE Salisbury and Woomera)*, 2nd ed., November 1952.
32. Reminiscence of Jack Redpath, then manager of Saunders-Roe at WRE, who probably holds the record with thirty-four return flights on the courier service.

10 Dropping bombs in the clear desert air

INTRODUCTION

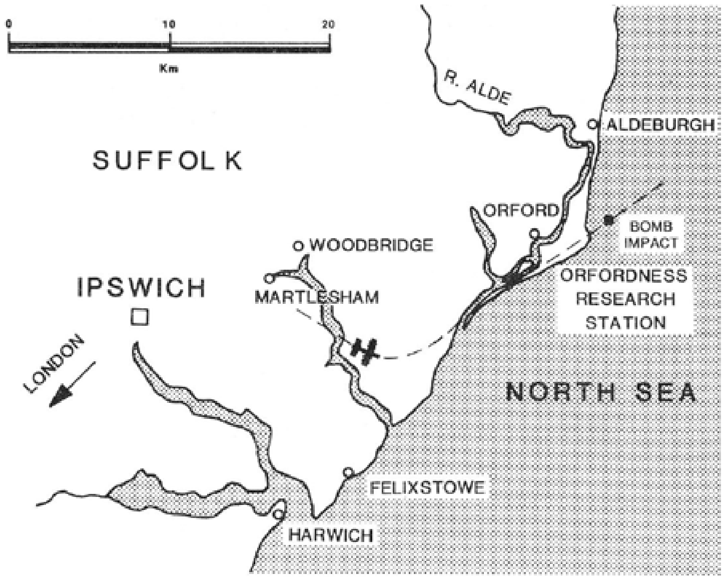
The first trials held at the Range were not of rockets at all but of bombs and other objects dropped from aircraft. The pioneering operation started in December 1947, when Woomera was little more than a construction camp; it was a campaign in which parachutes were dropped from fairly high altitudes. Next came a two-day exercise in September 1948 when bombs fitted with proximity fuzes were dropped on a temporary range at Shell Lagoon. Then in March 1949 the first bomb was dropped on the new permanent bomb ballistics range (Range A) just five days before the first simple solid propellant unguided rocket shot up from a temporary missile range. Both were preliminary exercises to train operators and check out equipment and procedures. Within a few years nearly all of the precision bomb ballistics trials needed by the RAF and the other British services were being done at Woomera. By the mid-1950s nearly 1800 bombs had hit the small target area at Range A, and on an extension of the range (Al) an experimental gliding bomb weapon called Blue Boar was tested until the project was cancelled. There were also over 1500 drops of proximity-fuzed bombs on a separate range on the dry salt bed of Lake Hart (Range B). The size of bombs tested during this and later periods ranged from 10 kilogram practice bombs to monsters weighing 4.5 tonnes, and while none were live some were ballistic dummies of bombs intended to carry British nuclear warheads.

Until 1955 the trials of objects dropped from aircraft were organised separately from missile trials, and there were parallel groups of Missile and Air people at Salisbury and Woomera to plan, instrument, carry out and reduce the data for each. At the 1955 amalgamation of the facilities at Salisbury, both activities were integrated into the newly formed WRE. By mid-1957 all air trials had been transferred to Range E (the main range), and from that time all Woomera trials were conducted on that one range. The story told here of air trials, of dropping bombs in the clear desert air, really ends in 1957 when it merged with the broad flow of activity at Woomera.

ORIGIN OF THE BOMB BALLISTICS PROJECT IN 1946

Bomb ballistics is the study of the flight of bombs dropped from aircraft. If it were not for atmospheric drag, a falling bomb of any size, shape or mass would follow the same parabolic curve to the ground; a curve easily calculated from the position, height and velocity of the aircraft at its release. Any bomb could then be dropped so as to hit its target accurately by using a simple bombsight set to the aircraft's height and velocity. But drag cannot be ignored, particularly for high altitudes, fast aircraft and light or non-streamlined bombs. To bomb accurately one must know the drag or ballistic characteristics of the particular design of bomb and then use a more complex bombsight able to compensate for these characteristics.

At the time this story begins, the traditional method of determining the ballistics of bombs was to drop full size samples, inert but otherwise ballistically identical[1] to the actual bomb type, on an instrumented bomb ballistics range. Normally the whole path of their trajectories was not determined; just the two endpoints of release and impact. To determine the end-points the following quantities were measured: the time of release and (in three dimensions) the aircraft position and ground speed at that time; and the position and time of the impact.[2] Wind speed and direction were also measured at release and at several



Top: The small UK coastal bomb ballistics range at Orfordness Research Station. Here plans were laid in 1946 for an 'ideal' land range for high altitude bombing trials in Australia.

Top left: R. P. Bonnell who co-ordinated the early UK planning for the Australian range.

intermediate heights so that trajectory could be corrected to still air conditions. The trials were repeated at many different release heights and speeds, and from the accumulated end-point measurements the ballistic index of that type of bomb was computed, as well as the dispersion or scatter about the mean trajectory.

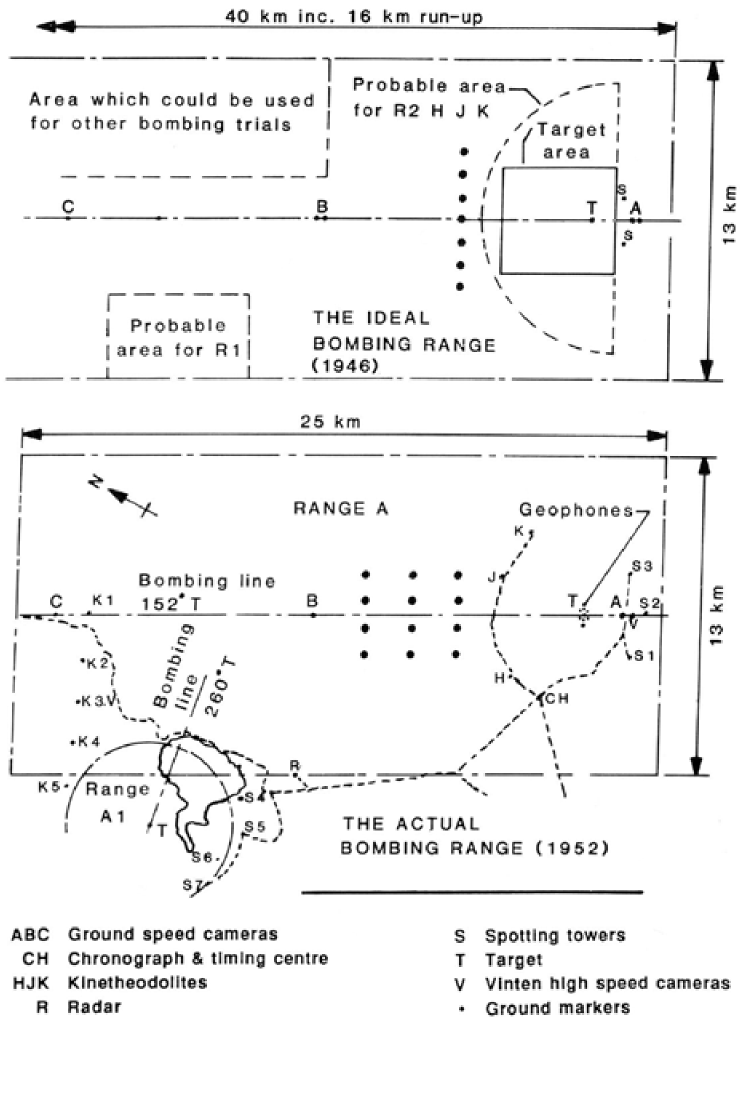
In 1946 Britain had many RAF practice bombing ranges but only one bomb ballistics range, and that was a coastal range at Orfordness Research Station (ORS), an outpost of RAE since March of that year. It was on a narrow neck of land, almost an island, on the east coast of England near the Suffolk villages of Orford and Aldeburgh. This range used optical instruments to measure the end-points. The aircraft flew in a straight line out to sea and released its bomb when it was directly over a 'ground speed camera' on the shore. This was a camera fixed to point vertically upwards and previously calibrated by photographing stars in the night sky. While the bomb was being released the camera took a multiple exposure photograph of a light mounted on the aircraft, and at the same time a camera in the aircraft photographed a surveyed pattern of ground markers from which its height could later be determined. The exposure times of the ground speed camera were recorded on a chronograph, together with the time of bomb release which was radioed from the aircraft to the ground. From all these records the release position, time and ground speed were computed. The bomb always fell into the sea, and high speed cine cameras on the shore recorded the position and time of the impact splash. The ground speed and air cameras were useless if their view was obstructed by cloud or fog, and consequently trials at Orfordness were at the mercy of the fickle English weather. In particular, trials from high altitude were only possible on the few very clear days each year. The growing need just after the war to do more and more high altitude trials lay behind the decision to move the work to Woomera under the joint project, although the idea of an Australian bomb ballistics range did not emerge until after Evetts had submitted his report in May 1946 and returned home. It developed quickly, however. Orfordness already had its long experience with bomb ballistics to draw on, and some of the equipment needed for high altitude trials was already in use there or was being developed.[3]

Though it was considered briefly, the complete transferral of the Orfordness staff and facilities to Australia was impracticable. Most of the equipment was not mobile but an integral part of the station, and to have transplanted it all wholesale would have disrupted the existing trials programs for a long time. In any case, a functioning bomb ballistics range close to the bomb design centre in Farnborough was a valuable asset. So under the plans finally adopted Orfordness would continue to be used for trials at low and medium aircraft heights and speeds. The Australian range would be used for medium to high altitude bombing from around 60 000 feet at near sonic speeds—the sort of performance to be expected from the V-bombers whose specifications were being drawn up.

Responsibility for all air trials including bomb ballistics had been assigned to Sidney Hunwicks of the embryo LRWO, which in late 1946 was still in Britain. Experts in bomb ballistics at Orfordness and at its parent Armaments Department at Farnborough would do the detailed planning. R. P. (Bob) Bonnell had just joined Hunwicks in the LRWO and was given the job of project officer for the task, with a roving commission to co-ordinate the planning. He was also to help get ready all the facilities, instrumentation and other equipment that would be needed to establish a bombing range in Australia. Bonnell had one office in Farnborough, another in the temporary headquarters of the LRWO in central London and a third at Orfordness, and he travelled often between the three. Hunwicks went to Australia with the main party of the Evetts eleven, but Bonnell stayed behind for some time to complete the preparations before flying out to join Hunwicks.

The key figure in planning the Australian range was George Hicks, a mathematician and Senior Scientific Officer in charge of the bomb ballistics section at Orfordness. Hicks had long dreamed of a range somewhere without the real drawbacks of Orfordness, which quite apart from the weather was so close to a busy shipping lane that during trials observers had to be constantly on the watch for vessels passing by. Now with the prospect of the transparent skies and empty spaces of the Australian interior at his disposal, Hicks rolled up his sleeves and set his ideal down on paper. It would be a land range, of course, and Hicks did not skimp on its dimensions: he thought that it should be 40 kilometres long, 13 kilometres wide and 18 kilometres high (25 by 8 miles by 60 000 feet high). The illustration shows the layout of this ideal range and for comparison the actual range later established at Woomera.

Hicks's plan went into the 'Bible', together with an outline of what was to be measured during bomb drops, the instruments required to make these measurements and where they were to be sited.[4] The instrumentation could not be a mere copy of that at Orfordness, for the techniques used at Woomera had to take into account certain peculiar advantages and disadvantages of doing the work on a land range. One advantage was that the bombs, or their shattered remains, could be recovered after impact. Another was that the instruments could be placed in the best possible position for accuracy. Against these advantages, one difficulty was recording the point of impact. At Orfordness, cine cameras were successful



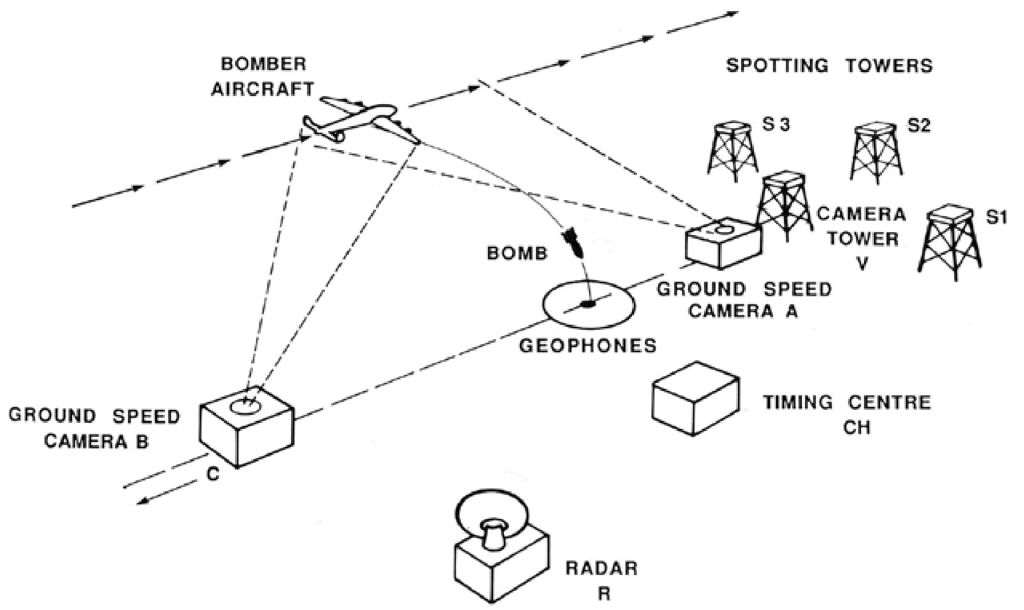
Shown right is the layout of the 'ideal' bomb ballistics range. It was closely realised when Range A, shown below, was established at Woomera in 1948. The Range A1 extension was added in 1952 for the short-lived Blue Boar guided bomb.

in positioning and timing the splash of the bomb into the sea, but they might not do so well in capturing the dust cloud raised by the bomb on land. Hicks decided not to rely solely on these cameras. Drawing on what he had seen of American methods, he planned to install a series of geophones to pick up the seismic waves created by the impact, and to use their records to calculate the exact impact time. There would be no difficulty in fixing the exact impact point much more precisely than was possible at Orfordness. One could make a ground survey of the impact crater, locating it quickly from rough bearings taken on the impact dust cloud from three spotting towers sited in an arc behind the target area. This meant, however, that the bombs would have to fall into a fixed impact zone and thus start their downward trajectories at variable release points, rather than the other way round as at Orfordness where the bomb was always released directly over the ground camera. This in turn meant an arrangement considerably more complex than the single ground speed camera looking straight up and an air camera looking down to triangulate the release point. Hicks decided to set up three ground speed cameras directly under the track of the aircraft, with one in front of the release point (camera A) and the other two behind it at B and C. They would be used in pairs: A and B for low to medium altitude drops, A and C for high altitudes. These cameras would be high performance devices built especially for the job.

At this time interest in bombing trials was starting to extend beyond the traditional end-point ballistics. At Orfordness optical tracking instruments driven by the radar had already been used to track bombs after release; the operators reported on any oscillation or other behaviour seen through the telescopes. With the clearer Australian conditions, this optical tracking ought to be possible at higher altitudes. Orfordness had also tried using Askania kinetheodolites to track the entire trajectory of the bombs from release to impact, and three of these were proposed for Woomera too.

The plan was for the Australian trials to proceed in stages as the equipment became available. At first, only one ground speed camera would be in place and this would be used with an aircraft camera photographing ground markers in an Orfordness arrangement. In the second stage the fully accurate end-point ballistic trials would start using two cameras, initially at lower altitudes until all three cameras were in place. In the third stage complete trajectories would be computed from kinetheodolite records. A final stage, involving the fitting of telemetry devices to the bombs to transmit their yawing and other motions during the fall, was not reached until bombing trials were transferred to Range E a decade later. The 'Bible' also mentioned two rather different projects using the new range. One was a series of high altitude unmanned parachute drops. The other was experimental work involving the dropping of bombs fitted with the new radio proximity (VT) fuzes.

These plans for the Australian bomb ballistics range were recorded in the 'Bible' in much more detail than for the main and the subsidiary rocket ranges. Only the sketchiest plans were available for the latter in 1946, and afterwards they developed along quite



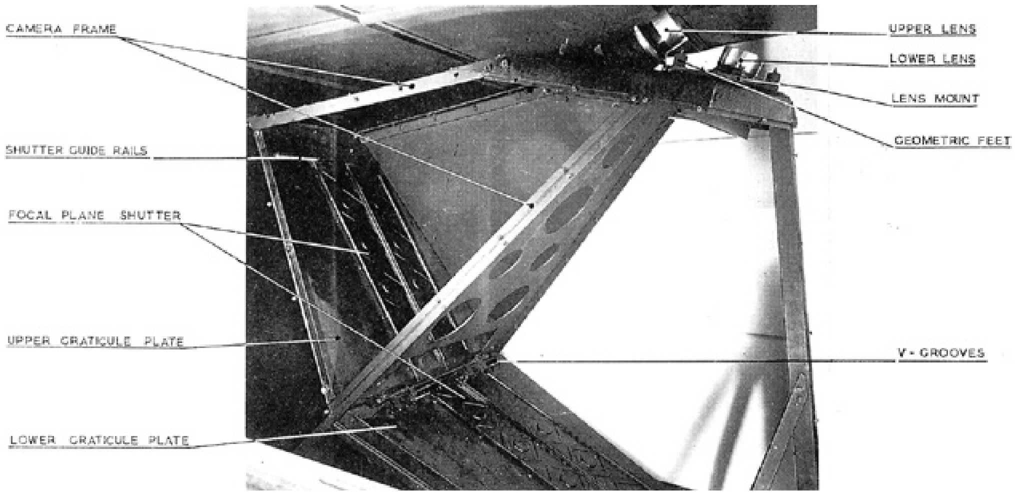
UK provided three special 'ground speed cameras', to be used in pairs to measure the bomb release point and aircraft ground speed by triangulation. Geophones in the target area would record the time of bomb impact.

different lines or not at all. By contrast Hicks's ideal bomb ballistics range was actually built much as he had envisaged it, though not without some small changes and a heated debate over where to put it.

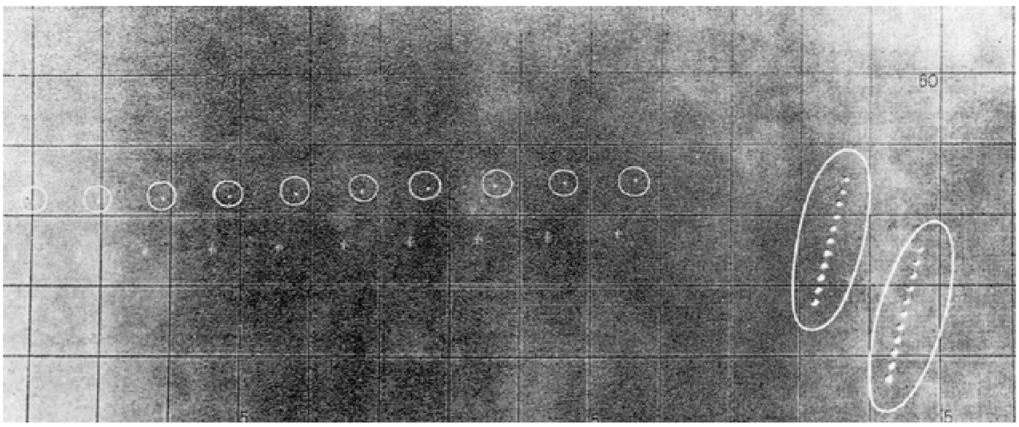
THE SHOPPING LIST FOR AUSTRALIA, 1947-48

Making plans on paper was the relatively easy part. Once they had finished their contributions to the 'Bible', Hicks and his staff and Bonnell turned their attention to getting hold of the actual instruments, aircraft, bombs, documentation and spares.[5] At Orfordness, Farnborough and elsewhere people were put to work designing, developing, manufacturing and otherwise buying or scrounging what was needed. Most of the items on the long and growing shopping list would have to come from Britain, as all that could be expected from Australia in these early days would be facilities such as roads, buildings, power, communications and the like.

The major items were the three ground speed cameras. They were designed from Hicks's basic concept by E. J. Petherick of Orfordness and built at Farnborough. Much work went into meeting their exacting specifications. The ground speed camera was really a dual camera. In effect two cameras were mounted on the same frame and each looked at a different part of the sky, although with a small overlap. The two lenses were of long focal length (1500 millimetres) yet of wide enough angle so that the dual camera could cover a strip of sky from near the horizon to the zenith along the track of the aircraft as it passed directly overhead. The dual cameras were designed to be stable, permanently fixed devices that once calibrated would remain accurate for a year or so. They were large—taller than a man and twice as long—and each was mounted on three independent concrete bases to minimise vibration, and housed in a large insulated container which was permanently air-conditioned to a precise 23°C to maintain the calibration.[6]



An illustration from a 1952 manual on the ground speed camera, showing its dual construction.



A record from this camera, showing multiple images of a bomber aircraft landing lamp (ringed) and of a Mustang aircraft flying alongside. The larger rings enclose smoke puff images from which wind speed and direction were computed.

The exposure times of the two ground speed cameras to be used in the trial was recorded on a chronograph at another site, 'CH', together with timing pips and the bomb release signal radioed from the aircraft. From these times and a painstaking measurement of the images of the aircraft lamp on the films from each camera, the position and ground speed at release were calculated by triangulation. The chronograph had twenty fixed pens that recorded event times by making marks electrically on carbon-backed Teledeltos paper. It was being used at Orfordness, but it was new and somewhat unreliable and needed more development. Despite its mnemonic code, CH housed more than a chronograph: it was the timing and control centre for nearly all the instruments. The timing heart beat was sent out from a Muirhead 1 kilohertz tuning fork, kept in vibration electronically and housed in a temperature stabilised oven. Its output drove a phonic motor clock fitted with hundredth and tenth second contacts that in turn marked the chronograph with the timing record.[7]

At Orfordness an American SCR 584 radar was used to track the aircraft and display its position on a plotting table, recently developed by the Bell Telephone Corporation. The aircraft was navigated from the ground by radio command and told to release its bomb when it reached the right point at the right speed and direction. Unfortunately there were no spare radars or Bell tables for transfer to Australia. However, a new British anti-aircraft tracking radar, the Army's AA No. 3 Mk 7, was just becoming available. Designed for jungle use in Burma, it was a 10 centimetre (Sband) set producing a narrow pencil beam, built into a small mobile van with a powered dish on the roof. Once the operator had locked on to the aircraft it would automatically follow it. This radar could run a plotting table through a converter, so Bonnell asked for four of them plus four plotting tables built under contract by EMI, whose engineers copied the Bell table while it continued in use.

Special bomber aircraft were needed for the high altitude trials. The new piston engined Avro Lincoln, developed from the famous wartime Lancaster, was chosen because of its generous bomb capacity. Three of the Lincoln B Mk 1 aircraft were modified for the task by the firm of Scottish Aviation, who stripped them of non-essentials and fitted new high performance Merlin 86 engines. Thus modified, the Lincolns could reach 35 000 feet, although they had no hope of matching the performance of the V-bombers, which would be flying half as high again.

FINDING A PLACE FOR A BOMBING RANGE

When he arrived in Adelaide late in 1946 as Chief Scientific Officer of the fledgling Long Range Weapons Organisation, A. P. Rowe quickly took up the question of siting a bomb ballistics range. Here Rowe was a little out of his depth. Although he had worked in bomb ballistics many years before, he had taken no part in the planning of the new Australian range and he had not consulted those who had. He had, however, a clear notion of where the range ought to be: close enough to Salisbury, he thought, for the trials staff to travel there and back each day. Rowe wrote to the State Premier, Tom Playford, saying that he was wholly against bomb ballistics being done at the rangehead, where the numbers of staff should be kept at a minimum. He asked Playford to help him find a few square kilometres of suitable land somewhere near Salisbury. Probably at that stage Rowe had yet to see the Orfordness plans for a far bigger ideal range of 40 by 13 kilometres, which would of course be much more difficult to locate in the settled agricultural lands just north of Adelaide.

The rest of the Evetts eleven were then at sea on their way to Australia. Rowe cabled to the ship at Colombo and asked Hunwicks to appraise his proposal en route—an impossible task with few documents, no maps and no facilities on the abominably crowded A*sturias*, still set up as a troopship and jam-packed with migrants and returning servicemen. But Rowe was impatient for a decision. Just three days after Hunwicks arrived, Rowe took him up to look at the Army's proof range at Port Wakefield, on the shores of St Vincent's Gulf and some 65 kilometres north of Adelaide. Hunwicks thought this was an extremely unsuitable site: it was much too small and too close to the main Adelaide-Perth highway. Rowe then asked him to examine a RAAF practice bombing range south of Port Wakefield, near Lower Light and Port Gawler. After a preliminary look Hunwicks said he would need time to work out where the facilities might be sited. Probably he would have to consult Britain. If Rowe insisted on an immediate answer, then it would have to be 'no'.

Rowe had to retreat, for Hunwicks was indubitably the expert: during the war he had specialised in conducting full scale armament trials, albeit for rockets rather than bombs. As Hunwicks recalled it:

> As this investigation proceeded I liked the idea less and less. I was convinced that the area was too small, I did not wholly accept Rowe's point about keeping numbers at the rangehead to a minimum, nor did I accept the extreme urgency—it was more important to get the right answer than save a few weeks. I felt I was being pressed to back a decision already made and that I was being pressed to do so too quickly and with insufficient technical knowledge—I had had long discussions with ORS staff in Britain and between us we had written a pretty comprehensive brief but never in our wildest dreams (or nightmares) had we ever thought of a 'small' range. Rowe and I had a number of arguments . . . he was adamant.[8]

Sidney Hunwicks

Still, having voiced his objections, Hunwicks duly went ahead with the search. He concluded that a small 8 by 5 kilometre range could be set up along the coast by acquiring one small grazing property. It would fall far short of the Orfordness ideal of 40 by 13 kilometres, but it might do for the first few years. Rowe accepted it with alacrity, and recommended to his chief Evetts that the Port Gawler-Lower Light area be chosen, at least for the time being. Later trials could be transferred to Woomera if necessary. Evetts supported Rowe and the newly formed Board of Administration approved it in principle on 5 June 1947, subject to cost estimates of land acquisition and facilities. Despite Hunwicks's objections, all seemed set fair for a bombing range within a commuter trip from Adelaide.

Then the British reacted, quickly and decisively. At a meeting held at Farnborough late in June to consider the Australian move, it was concluded that

> the area of 5 by 3 miles available at the proposed site is much too small for high altitude bombing. Such a proposal is, in fact, somewhat disconcerting as it would appear to show a lack of appreciation of the problem by the LRWOA.[9]

The bombing range should be at Woomera with the missile range anyway, so that one staff could look after both. It was also recommended that J. W. Frame, head of Orfordness and thus Hicks's chief, should fly to Australia on his way back from a forthcoming visit to US bombing ranges and discuss the proposal.

There was little argument from Australia. The tussle between Hunwicks and Rowe had now fallen flat as the latter had left for a new job. Evetts accepted the British view after talking it over with G. W. H. Gardner, Director of Guided Weapons R&D in MoS, during the latter's visit early in July 1947. Without more ado Hunwicks was sent off to Woomera to find a place for the full size ideal range.

This search was not as easy as it might appear. The target area, about 3 kilometres in diameter, had to be quite flat; and as geophones were going to be used the underlying rock strata had to be horizontal at least to a depth of 150 metres. The bombing line was to run south to north to avoid sun glare, and each of the three ground speed camera sites on this line had to be within half a centimetre of the same height above sea level. The bombing range and the flight paths of the aircraft using it had to be clear of the future main range and Woomera airfield, while still being conveniently close to the village. The specifications were rigorous, but Hunwicks came up with a promising range area north of the Woomera airfield site, between Shell Lagoon and Lake Richardson. After arranging for a geological inspection he selected suitable spots for planting geophones at the northern end of this area.

Frame arrived in Australia from his tour of US bombing ranges in early October. On the same day Bonnell arrived from Britain to join Hunwicks. The three of them visited Woomera with a geophysicist from the Bureau of Mineral Resources, and made what they hoped would be the final selection of the bombing range. They picked a target point between Shell Lagoon and Red Lake. The bomber would do its run-up over Lake Richardson and head towards this target on a bearing of a little west of due north, which would allow trials to take place throughout the morning without the sun dazzling the cameras.

Butement secured the approval of the Board of Administration in November, subject to a favourable geophysical survey, and Evetts (then in London) was told that the bomb ballistics range had top priority. On his return late in December 1947 Evetts instructed that it should go ahead immediately.

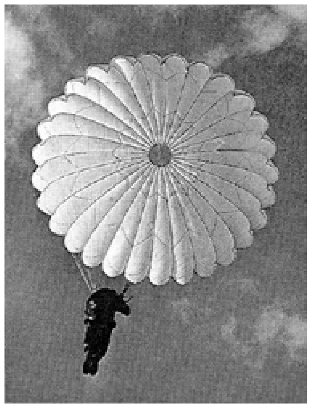
There was however one more change to come. Somebody (possibly Butement) pointed out that the busy part of the range around the target was really at the wrong end, as it was furthest from the village. Why not turn the range around so that the bomber approached from the north rather than the south? The target would then be at the southern or village end, which would save travelling time in manning the range each day and would save money spent on communications lines as well. Further, the ground marker pattern (to be photographed by aircraft cameras in early trials) would not have to be sited in the sandhills of Yandandarre Ridge. The change would make no difference to sun interference. Hunwicks looked at this suggestion and agreed, provided the southern target area proved satisfactory for geophones. The geophysical test was extended to the newly proposed target area, and it was found that while both places were satisfactory, the new southern one was actually better. The final decision was then made in March 1948 to reverse the range end for end, which gave final definition to Range A. The search for a site was over.

The building of the range by the Department of Works began at once, with a target completion date of 1 July 1948. The date slipped a little, but the construction was virtually complete by 1 October, apart from buildings for the three kinetheodolites and the third ground speed camera C, none of which was needed for the first phase of trials. The communications cables connecting the instrumentation sites were still being installed by an Army signals unit but were promised to be ready soon. The power line back to the Technical Area powerhouse had been delayed, but generators were operating at each site. The whole range had been virtually finished within a few months of the original target date set back in 1946. Bonnell's contribution to this success had been a major one:

> For two years from about November '46 the Australian BB Range dominated all my waking hours, to the exclusion of practically everything else. It had to if the project was to be completed on or near schedule. It was certainly worth all the effort when in November '48 I was proud to [hand over] responsibility for the last of the permanent ranges to be added to the 'Bible' in England, but the first to be completed in Australia.[10]

WOOMERA'S FIRST TRIALS: PARACHUTES

Early in 1947, while Rowe was still looking for a small range near Salisbury, Farnborough was investigating some problems with the escape parachutes used by the RAF. During the war it had been discovered that when the conventional parachute was used in an emergency at high altitudes it could open with dangerous abruptness and violence. The shock loads could damage the rigging lines or canopy, and in one case a Spitfire pilot who bailed out at 42 000 feet had been badly injured by the terrific jerk on his harness. As part of its investigation RAE was planning trials in which parachutes fitted with dummy loads would be dropped from heights of up to 30 000 feet (9 kilometres). None of the dropping areas in Britain was really adequate for drops from this height, as the unmanned parachutes could drift a long way outside the safety limits. Thus the idea surfaced of doing the trials on the new Australian bomb ballistics range: the large one that the British were expecting to see, not Rowe's small substitute. Apart from the inherent advantages of using Woomera such as the better weather, parachutes would give the new organisation a chance to cut its teeth on a straightforward piece of work.



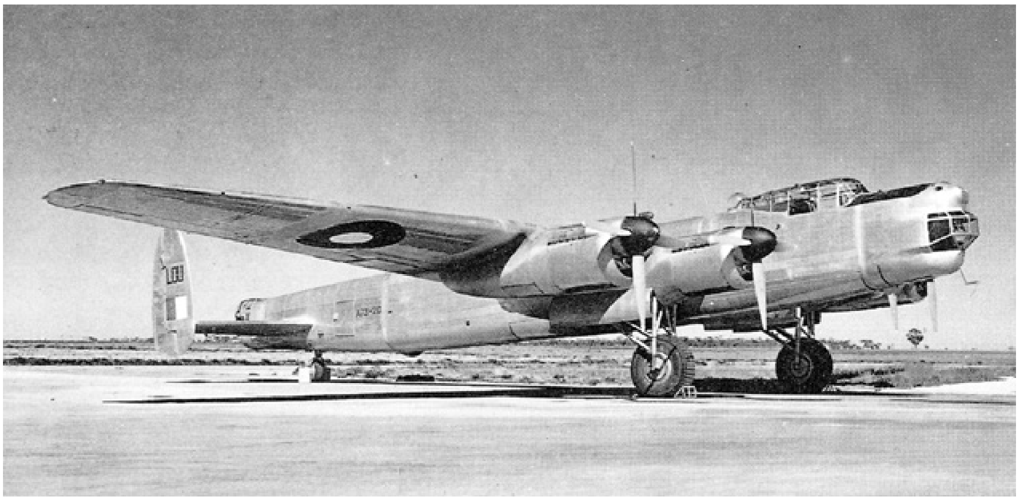
A RAF practice jump in 1945. Wartime problems with emergency parachutes used at high altitudes led to Woomera's first trials campaign. (RAE)

By June 1947 it had been agreed that W. D. Brown, the chief of RAE's Parachute section, would go to Australia to conduct these trials. Brown needed an air observer, and his deputy, Sidney Jackson, who was not keen to go to Australia, nominated another man, Picken, to go instead. Off went Jackson to France to do some wind tunnel tests and to visit a parachute training school at Pau, after which he moved on to Geneva for his holidays. He recalled later:

> I arrived in Geneva, looking forward to the holiday after a 15 hour journey overnight by train from Pau. Only two days after . . . I received a cable from Brown which read: 'Come back at once to go to Australia. Picken failed decompression test.' I was furious at the interruption.[11]

As it turned out, Jackson could well have stayed in Switzerland. It was the end of October before he and Brown flew from England aboard a Vickers Viking being delivered for use as VIP transportation between Mallala and Woomera.

In the meantime Salisbury was busy planning for the trials. They were 'air' trials, so the responsibility again fell to Hunwicks. The task, though small, was actually far from routine. The bomb ballistics range was still only an idea; Frame and Hunwicks had only just agreed on where it was to go. There were no rangehead facilities, no experienced trials planning staff and the British experience with parachutes—all there was to draw on—was



Australian built Lincoln bomber A73-20 which dropped the parachutes in these early trials

not entirely relevant to Woomera conditions. A target area was selected just off the route of the future road to Koolymilka, an area later occupied for a while by Range G. The Lincoln bombers intended for the bomb ballistics trials were still being modified in Scotland for high altitude work, so an Australian-built Lincoln B Mk 30 (A73-20) was prepared at Point Cook by stripping it down to the bare bones.

After some legal problems—the Range did not formally exist at this early date—everything was made ready. Trials Instruction No. 1 had been written, and the Range, RAAF and Security orders promulgated. The responsible officers had been appointed, the Army and RAAF operators at Woomera selected and briefed, and their equipment set up and checked. While waiting for the legal hurdle to be cleared Brown and Jackson had dropped a few parachutes on to the beach at the Port Wakefield Proof Range and had satisfied themselves that the flying side was ready to go. The normally genial Brown was not so happy with the fact that he was not in scientific charge of the trial. After all, he and not Hunwicks was the expert on parachutes. As it happened, Hunwicks was rushed into hospital with appendicitis during the trials so Brown was put in charge anyway. The argument was softened by the fact that Brown and Hunwicks were old friends, and were to remain so until Brown's death in 1984. In any case, while seeing the Australian point of view Hunwicks agreed with Brown, feeling that anybody who was not an expert could not possibly be in 'scientific charge'.

On the morning of 5 December 1947 the Lincoln took off from Mallala and headed north for Woomera for the first trial, with its RAAF crew and the lone Englishman, Jackson, huddled in the tail turret as observer. He had previously helped to prepare the parachutes by measuring their porosity, packing them, loading them into the Lincoln's bomb bay and attaching their 90 kilogram loads. The Lincoln flew at 10 000 feet over the freshly graded stretch of dirt that was Woomera's first airstrip, and after the control tower had signalled all was ready, the pilot released the first parachute. The airborne camera photographed the release while Jackson observed its behaviour and timed its opening with a stopwatch. On the ground, observers with binoculars and stopwatches had been stationed at the control tower and another post 11 kilometres away, and they timed the parachute's slow descent to the ground. Using prismatic compasses they took bearings of the impact point from the two observation posts and plotted the impact point on a map.

The Lincoln dropped seven more parachutes and then flew back to Mallala to prepare for the next day's trial. Meanwhile Brown and the recovery party headed off in a jeep to recover the parachutes, driving slowly and cautiously to avoid the larger boulders and marshy patches. Help in finding them came by radio from the two observation posts and from an Auster circling overhead. Brown examined each parachute where it lay with its glaring white fabric spreading over the sunbaked gibber stones, and jotted down his findings on his log sheet. Later the eight parachutes were bundled up and loaded on to an RAAF Dakota waiting on the dusty airstrip, then flown back to Mallala for Jackson to examine more thoroughly.

The parachute trials continued until late January with a three-week break while the range operators were sent off to the cooler south on their promised Christmas leave. The break was not so welcome to Brown and Jackson, who were not expecting it and were too far from home to benefit. Nevertheless, they could take comfort in the fact that a total of 209

RAE parachute expert Sidney Jackson huddled in the rear gun turret.

parachutes were successfully dropped and recovered during the six working weeks of the trials campaign. The single available Lincoln aircraft made twenty-five daily flights to and from Mallala, lost practically no time because of unserviceability and on five flights achieved the desired altitude of 30 000 feet. It was the first time any aircraft had flown so high over South Australia, and although the trials were held in secret there was no disguising the condensation trail. As Jackson recalled it:

> We were flying one day against a 100 knot headwind to Woomera, struggling at 90 knots ground speed at 20 000 feet above Whyalla and making a simply beautiful vapour trail. A picture of this appeared in the Adelaide evening newspaper with the caption 'Mystery vapour trail above Port Augusta'. Next day there was a learned explanation from the Professor of Physics at Adelaide University, ascribing the phenomenon to a meteorite.[12]

Another incident aloft was not so amusing. The timebase for the aircraft camera was produced by a tuning fork fitted with a pair of electrical contacts which sparked a good deal. This unit was mounted near the main fuel cock. On one of the earliest flights a strong smell of petrol revealed that the cock was leaking. Hurried consultations ensued. When the timing unit was switched on for the drop could its sparking ignite the vapours swirling around? Jackson thought not, but was not sure. He recalls the pilot saying resignedly, 'If we blow up you will know why'. Fortunately the leak disappeared as they climbed higher on the way to Woomera, so the trial went ahead. Despite desperate efforts by the Mallala ground staff to cure the leak it proved obstinate and persisted for a few more flights. Soon after this Jackson developed a rash which a RAAF consultant dermatologist diagnosed. He said it was not infectious, and was often caused by tension: was Jackson worried about anything?[13]

Brown stayed at Woomera on the weekdays. The village was nothing more than a few surveyors' pegs, so he slept in a tent in the army camp near the airstrip. It was hot and dry and dusty, with temperatures hitting 44.5°C in the shade, but at least there was a refrigerator in the mess marquee tent to keep the beer cold. At the close of the trials campaign a VIP party, including the South Australian Governor, Sir Willoughby Norrie, came up. Brown was to be presented, and the Governor's aide de camp, Viscount Althorp, was dispatched to find him. Brown was discovered having a sponge bath in a small tub just outside his tent, attempting to make himself presentable by washing off the inescapable dust and sweat.[14]

So ended Woomera's very first trials campaign. Although simple enough compared with the complex operations of later years, it was a milestone in the lives of the inexperienced but enthusiastic staff at Woomera, Mallala and Salisbury who laboured over that hot summer to make it all happen.

UK parachute expert W. D. Brown who conducted Woomera's very first trials was bathing in a small washtub when summoned to meet the State Governor. There were no bathrooms in the early Army camp at Woomera.

BUILDING THE BOMB BALLISTICS TEAM

Bill Watson (*top*) and Jim Frost (below) were sent to Orfordness for training early in 1948.

The roads, buildings, power and communications for the bomb ballistics range were ready late in 1948, just as a second campaign of parachute trials was beginning. The time had come for the radar, chronograph and cameras which had been arriving at Port Adelaide to be installed, tested and calibrated ready for the first bomb drops. It was time too for the nucleus of the future bomb ballistics team to appear; a nucleus that had been planned two years before.

The 1946 'Bible' had contained a detailed assessment of the number of staff needed in Australia for the bombs work: fifty-three in all, made up of thirty-eight technical, administrative and industrial staff at the base and fifteen maintenance men at the range. The 'Bible' emphasised that an advance party of at least four people experienced in ballistics work, including the head of the unit, should go to Australia to supervise the laying out and equipping of the range. As there was not enough staff at Orfordness to provide this nucleus, new members had to be recruited quickly and trained at Orfordness.

Early in 1947 the size of the advance party was set at five rather than four. While the leader would clearly have to be an experienced bomb ballistics expert from Britain, the intention was for the other four to be recruited in Australia and sent to Orfordness for training. This was in line with the policy, described earlier, of integrating Australians into the Organisation. The advertisements for trainees appeared early in July 1947, and from the 300 applicants a short list of eleven was extracted of those who might be immediately suitable for Orfordness. (Things were done this way to save time, for Britain was pressing to have the four recruits over at Orfordness by the northern summer—an impossible schedule that was not met.) Four men were selected in August: two scientists, Bill Watson and Kevin Boyle; and two engineers, Peter Moran and Jim Frost. They were the first of more than 200 trainees to go to Britain under the scheme.

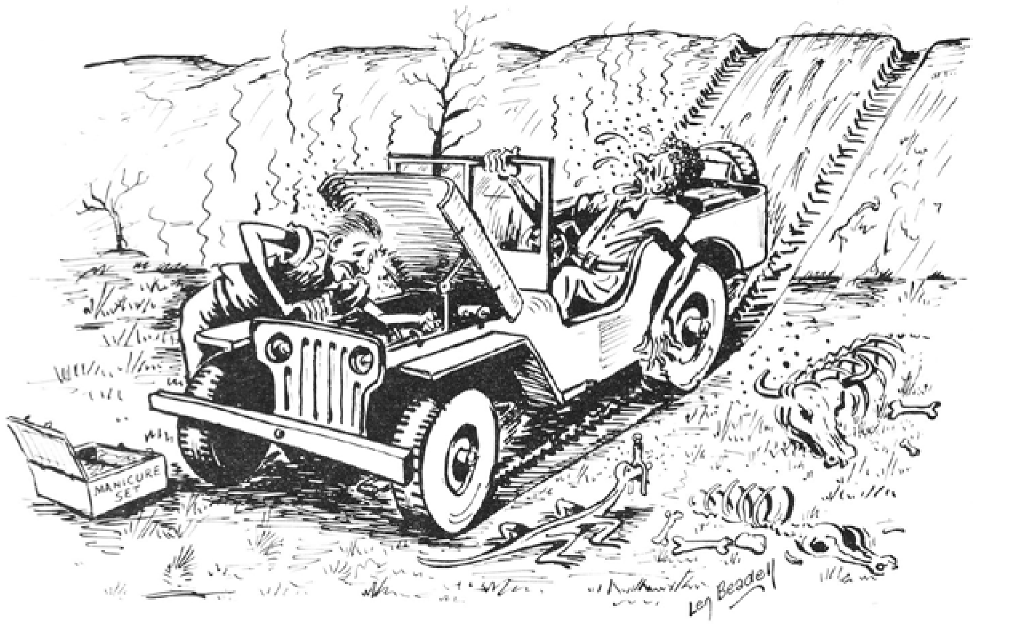
One of the four (Frost) recalled their early training period:

> I started work at Salisbury on 1 December 1947 on the same day as Peter Moran. Kevin Boyle was already there and Bill Watson was to join later. At the time there was only a handful of people at Salisbury concentrated in one corner of several square miles of empty buildings. Bob Bonnell introduced us to bomb ballistics, and also took us on our first ever visit to Woomera, in an uncomfortable RAAF wartime Dakota aircraft with hard seats. There we saw plenty of salt lakes and sheep, kangaroos, gibbers and mulga but nothing of the vast construction work that was to come later. Woomera village did not really exist then, and Tech Area was only a dusty airstrip, a few roads and two nearby camps mainly of tents: we slept overnight in a tent. Our party bumped its way in jeeps along rough station tracks to see the newly chosen site for the bomb ballistics range. There was a stop for lunch and another later while our Army drivers dug one of the jeeps out of a dry sandy patch. When we got to the site a geophysical test of the proposed target area at the northern end was in progress, but otherwise there was not a thing to see apart from the gibber and mulga stretching to the clear horizon. Like most Australians at the time we had been brought up in the south-east of Australia and this was our first contact with the vast arid interior. I found it too hard, dry and open, and it was a few years before I came to love it. It was to be familiar territory in the years ahead. A few weeks later Peter Moran and I left Rose Bay on a magic carpet, flying over tropical islands, extinct volcanoes, Egyptian pyramids and the rest until we reached England. It was the old Qantas/BOAC flying boat service using slow low-flying, high-winged aircraft, free of jet lag and giving an incomparable view of the world to two youngsters on their first overseas trip. We found Orfordness quite a contrast to Woomera. The first cold shock came from midwinter snowfalls and bleak North Sea gales so soon after century Woomera temperatures. But the English spring soon burst around us and we revelled in the daily commuting from nearby Ipswich through lovely rolling East Anglian countryside and thatch-roofed villages with ancient square-towered flint churches. Orfordness had a rather relaxed atmosphere. There were many bombing trials scheduled, in which we tried to do our bit, but many of them were frustrated by bad weather or shipping in the target area off the coast. The instrumentation for the Woomera bombing range was then being assembled and tested at Orfordness. Kevin Boyle who arrived first had been assigned the radars and plotting tables used to put the Lancaster and Lincoln bombers on the right course. Orfordness was using American SCR 584 radar sets but the newly developed Army AA No. 3 Mk 7 radars had been ordered for Woomera and arrived while we were there. Peter Moran took on the room sized ground speed camera and the intricate mechanism of the chronograph recorders, while I was given the electronic timing equipment and a noisy device known as the Master Control Box, which remotely switched all the cameras and recorders on and off. Our job was to find out how it all worked and to help with testing and modification. Bill Watson said he knew nothing about electronics or optics so he got the data reduction job, which suited the other three of us with our shared horror of mathematics. George Hicks was our boss: quietly spoken but with a will of iron and universally admired and respected.[15]

Back in Australia the early work on planning the range was being done by Hunwicks and Bonnell; but Hunwicks knew he had to move on soon to organise the recruitment of the scientific and technical staff needed for the new organisation. Filling the position of team leader was now becoming urgent. Hicks was of course the obvious choice, and fortunately he accepted and arrived with his family late in October. He was promoted and took up the post of Principal Officer, Bomb Ballistics Group.

Bonnell welcomed Hicks, briefed him on progress and escorted him on his first trip to Woomera. Much later Bonnell remembered that during this trip:

> I was driving the jeep through a sand hill and thick mulga bush area, taking a short cut, when the jeep developed intermittent engine trouble. Finally the engine completely stopped. We were in a hollow between two steep mulga covered sand hills, and right alongside the bleached skeleton of a cow—no road or track, only our own tyre marks in the loose sand behind the jeep, and our water bag was nearly empty. I wondered what George was thinking. A few days before he had been in a green and damp England and now it looked as if he was lost in the desert with little water, no food and an unserviceable vehicle.[16]



'Lost in the desert'

Fortunately Bonnell got the jeep going after a bit of manipulation with his nail file, and the two of them were back at the Woomera mess in time for a late tea. Hicks had got the message, though. Before departing on a later trip to the VT fuze range at Lake Hart he insisted on his driver checking the spare wheel and jack. The spare was dead flat.

After Hicks's arrival Bonnell, like Hunwicks, moved on to other fields, initially to planning the forthcoming VT fuze trials. In the years ahead he was to be the leader of a group working on optical instrumentation and optical research.

Now on his own for the moment, Hicks turned to the task of building up his team. Frost soon arrived from Orfordness to join him, but Moran and Watson stayed behind for a while to finish off some special tasks including, in Moran's case, redesigning the troublesome chronograph. Boyle had been the first of the four trainees to return, but he was keen to pursue his more specialised interests in electronics. He had already asked for transfer to the newly formed Electronics Group led by R. W. Boswell. As it happened there was at that time (September 1948) a newly recruited trainee in Electronics Group who could readily replace Boyle, and a two-way transfer was granted. V. J. M. (Jim) Bosher, a science graduate of London and Adelaide Universities, had been a Radar Officer in the RAF during the closing years of World War II and was familiar with 10 centimetre radar and the Oboe target marking system. He had served in the south of England, North Africa, Italy and Germany and was happy to delay (permanently, as it turned out) a further period in England as a trainee in order to set up the radar equipment on the bombing range.

Hicks divided his Group into two sections which he labelled 'Instrumentation' and 'Trials'. Bosher and Frost were in the first together with Gordon Brooks. They were joined by Moran when he returned from Orfordness in April.

The Trials Section started off with just one man, Flight Lieutenant A. H. (Bert) Young of the RAF. Bert Young had been a member of the Bomb Ballistics Unit based at Martlesham Heath that dropped bombs at Orfordness, and he was in the RAF crew that flew one of the Lincoln bombers from Britain to Mallala. Hicks gave him the job of organising all operations including early visits to Woomera as well as the trials that followed. Later he retired from the RAF and joined the Establishment as a civilian: he was the trials controller for bombing trials for some years afterwards. He worked hard and was a hugely convivial man, fond of women and tireless at mess parties. He was one of the many larger than life characters who gave colour to the early years of the joint project.

Bert Young, the hard-working trials controller.

Trials Section was also home to six Assistants (Female) Computing, who read the films and calculated the results. As will be described later, this tiny computing cell at the Establishment eventually grew into the large Mathematical Services Group. Watson returned from Orfordness later that year and became the king pin of data analysis; he had been thoroughly trained by Hicks.

At Woomera the ranges were then operated and maintained by servicemen. The Superintendent appointed a pleasant young RAAF Flight Lieutenant, Lin Smooker, to take

George Hicks (right) who came out from Orfordness to lead the bomb ballistics work in Australia. Jim Bosher (*left*) set up the radar equipment.

charge of range operations. Until the trials started he was to liaise with the construction people who built the roads, buildings and communications, and then give active assistance to Bomb Ballistics Group in the installation phase. He did both with considerable charm and aplomb. Smooker assigned his RAAF, Army and Navy technical specialists to the task of helping the Hicks team install the cameras and control boxes, the radars and radios and get them going. Later they took over the operation and maintenance. A RAN Petty Officer, Greg Sharp, became Frost's right-hand man with the timing and control. An Army Warrant Officer, Graham Webber, did the same for Bosher; he had been trained at Orfordness to operate the radars.

There was a third team, indispensable for bomb ballistics, and that was the RAAF flying unit based at Mallala and later at Woomera. We will have more to say about it later.

INSTRUMENTING THE RANGE

Once Hicks had gathered the nucleus of his team he pushed ahead with installing the instruments from Orfordness. The most critical task was setting up the first ground speed camera at Post A, which would be used along with the aircraft camera to fix heights by triangulation. The building with its three separate concrete foundations was ready. The camera had been shipped as a kit of parts packed inside a big steel container the size of a small room. This had already been squeezed through a movable wall section into its building, which it nearly filled. After unpacking the parts the camera was painstakingly assembled, precisely aligned, wired-up and tested electrically; most of this work was done inside the unventilated container body during the early summer, without benefit of air-conditioning. The assembly was complete by Christmas. Early in January 1949 the contractor was at last satisfied with the air-conditioning (which was there for the camera, of course, not the sweating workers). After a soak at a constant temperature for fourteen days everything was ready for the final stage. Following a photographic check to ensure that the lenses were precisely focused on infinity, the camera was calibrated by the most accurate method available, exploiting the fact that the angular positions of the stars are very precisely known. The method was to photograph the night sky at known times, then afterwards to identify the brighter stars and calculate their elevation and azimuth angles at these times from astronomical tables.[17] The photography part alone took up several rather boring hours of a clear moonless night, often late at night or early in the morning to ensure that enough bright stars were in view. It all had to be done again if the weather closed in or if not enough stars were recorded in parts of the graticule plates; and in any case it had to be repeated periodically, especially if the lens focus changed, if the lens or graticule was shifted accidentally, or if the air-conditioning broke down. Despite the overtime one could earn, this job was not very popular.

Twelve geophones were arranged in concentric circles around the target, each at the bottom of a steel-lined shaft 2 metres deep. They were being calibrated by a small team from the Bureau of Mineral Resources in Melbourne, who had fired off small charges at various points in the area and measured the time taken for the seismic waves to be detected by each geophone.

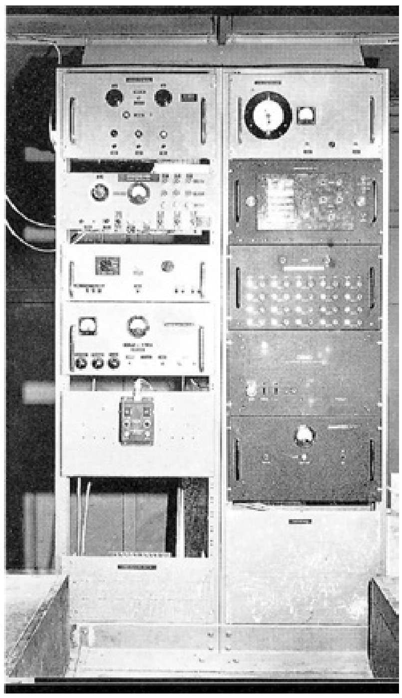
Meanwhile Frost was working hard on the timing centre at Post CH. Like the ground speed camera, the chronograph and timing equipment had been built into a heavy container body at Orfordness, and this also was placed inside its building through a removable wall section. Working inside the container body was rather cramped. It did not take long to get the CH equipment going, as it had already been assembled and thoroughly checked at Orfordness, but there were problems with the cables connecting CH to the other posts on the range. Because underground cable was in short supply, Army stocks had been salvaged from Morotai where they had been sent in the closing stages of the Japanese war. At least, that was the story from Captain Morrie Bennett's unit, which was doing the laying, whenever anybody complained of signals not getting through properly. The Mk 1 chronograph also gave trouble, as it had at Orfordness. Because of all these problems the whole timing and control network was not finished by Christmas as had been hoped. Hicks had a few sharp words to say about this, for he wanted it all going early in the New Year to calibrate his cameras and do the last checks before the bombs began dropping in February. Frost and Brooks spent twelve days without a break at Woomera, working late every night including the weekend. They returned to report that all was ready.

It was now Bosher's turn to set up the radar navigation equipment at Post R after a delay waiting for the predictor to arrive. By the end of February the No. 3 Mk 7 radar, the converter to match the radar to the plotting tables and the predictor were installed and working. This equipment had been designed for pointing guns at enemy aircraft, and the predictor's job was to correct the gun aim by calculating where the aircraft should be when the shells reached it. It had been modified at Salisbury to enable it to predict the impact position of the bomb. The plotting tables ordered from EMI by Bonnell were still being manufactured, so simple dial boxes were set up for the time being to display the aircraft position and the predicted impact position. The trials controller at Post R could then guide the aircraft to the correct position and give a countdown for release to the pilot and to all operators on the range.

In January 1949 the first two of the three modified Lincolns arrived from Britain. After removing their long range fuel tanks and navigation gear, the RAF ferry crews handed them over to the Mallala ground crew, who promptly discovered to general consternation that some batteries carried as cargo had leaked and that both aircraft were showing signs of acid corrosion. Both were grounded. Fortunately there were two standard RAAF Lincolns,

Below: Graham Webber setting up the radar converters and predictor at Post R.

Below right: The original timing equipment at CH supplied by Orfordness.



intended for the lower altitude flights: one of them was A7320, the veteran of the earlier parachute trials. They were fitted with enough equipment for the early training drops, and then each was flown in turn up to Woomera and along the centre line of the range, without dropping a bomb, in order to train the crew and the range operators on the ground. On 10 March one of the two grounded modified Lincolns (RE259) was returned to service, fitted with its special equipment—high power lamp unit, F52 aircraft camera, bomb release transmitter and the rest.

On 17 March 1949 the first bomb was dropped on the virgin range. It was a standard 110 kilogram bomb whose ballistic properties were beyond dispute; the drop was solely to check out the aircraft and ground equipment and procedures and to train the operators. Nevertheless, it was memorable as Woomera's very first instrumented trial, even if the instrumentation was not quite complete: there were neither geophone recorders nor a high speed camera to record the impact time. In the weeks ahead these deficiencies were overcome as the proving and training trials continued. By the end of the month a Vinten high speed cine camera had been placed on the tower behind camera A to photograph impact. By July the target area had been recalibrated and a six channel Miller recorder installed in a small van near CH: it would of course only record six of the twelve geophones but it served until a twelve channel recorder was available. The troublesome Mk 1 chronograph had been replaced by the much improved Mk 2 version that Moran had brought back with him from Orfordness. Two Askania kinetheodolites had been set up, initially alongside their little buildings until the latter were ready. The operators had little success tracking the small practice bombs, but hoped to do better with the larger 450 kilogram bombs to be dropped in the next phase. Still to come was the permanent mains power from the Technical Area power station, but mobile generators known as 'donks' were at each post, and while starting them each morning needed two fairly fit men, at least they usually worked. The second of the two grounded British Lincolns had been returned to service in April, and all was ready for serious trials up to medium altitudes, which started in late July.

The instrumentation on the new range, now officially Range A, was completed during the following eighteen months. Moran and his team installed the second ground speed camera at Post B early in 1950, and this improved the accuracy as the airborne camera method was only a temporary stop gap. The third camera went in at C in late 1950, and this gave full coverage of high altitude drops from the full 18 kilometre height. By this time the mains supply was coming from the Technical Area power station, the third Askania kinetheodolite had been installed and all twelve geophones were being recorded. The EMI plotting table was also in place at Post R. The instrumented bomb ballistics range that had been planned in Britain four years before was now a reality.

Norm Gerrard (*left*) examines the navigation plot on the EMI plotting table at R. He later took over the scientific direction of VT fuze trials.

INSTRUMENTATION DEVELOPMENT

In 1950 practically all the instrumentation at Range A was 'Made in England'. Over the remaining seven years' life of the range much of it was gradually replaced by devices made at Salisbury to the design of the young enthusiastic ex-trainees and others in Bomb Ballistics Group. Some installations changed beyond recognition, particularly CH.

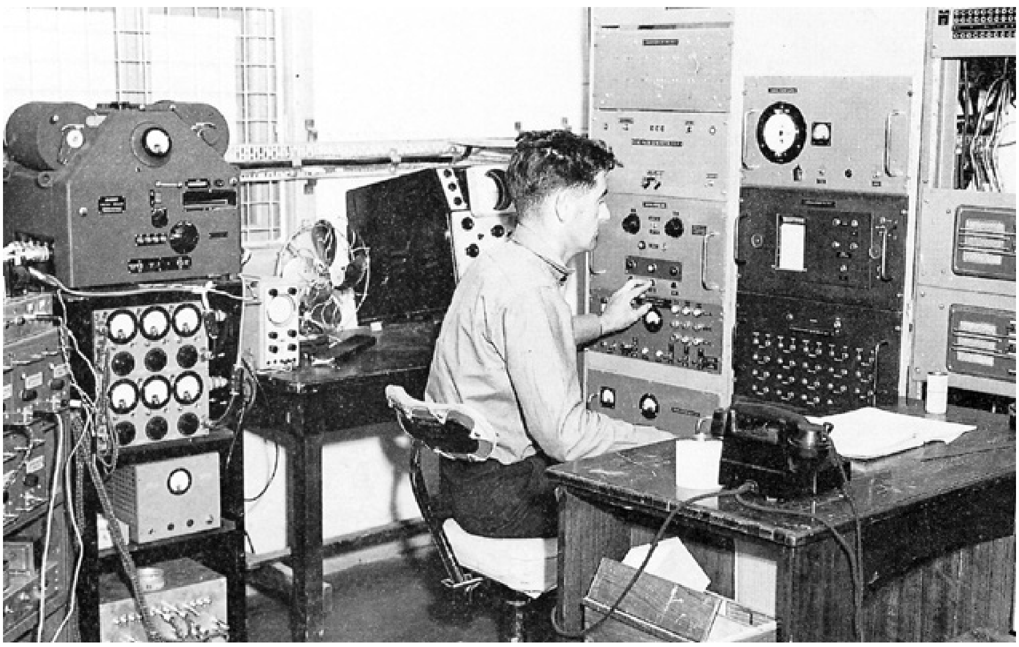
Least affected by this urge to develop and modernise were the three ground speed cameras, which were of very solid design. The calibration routine was automated somewhat, but that was all. At Post R the army tracking radar altered little externally, but inside the building the computing and display equipment was modified considerably as further gear was developed and added—so much so that the building had to be extended to hold it all. Most of this work was done by a specialist in pulse techniques, J. H. Clarke, who had had experience with the wartime British effort in radar development. Under Bosher's general direction, Jack Clarke developed several systems for improving the handling of tracking data and applying it to the control of the flight of the bombing aircraft. One of his initiatives was a Bombing Line (BL) system which indicated direct to the pilot of the aircraft how he should steer and when he should release the bomb to hit the target. Clarke's considerable knowledge of pulse techniques was an asset to others in the Instrumentation Section of Bomb Ballistics Group.

Jack Clarke, a specialist in electronic pulse techniques, developed early aircraft tracking systems for bombing trials.

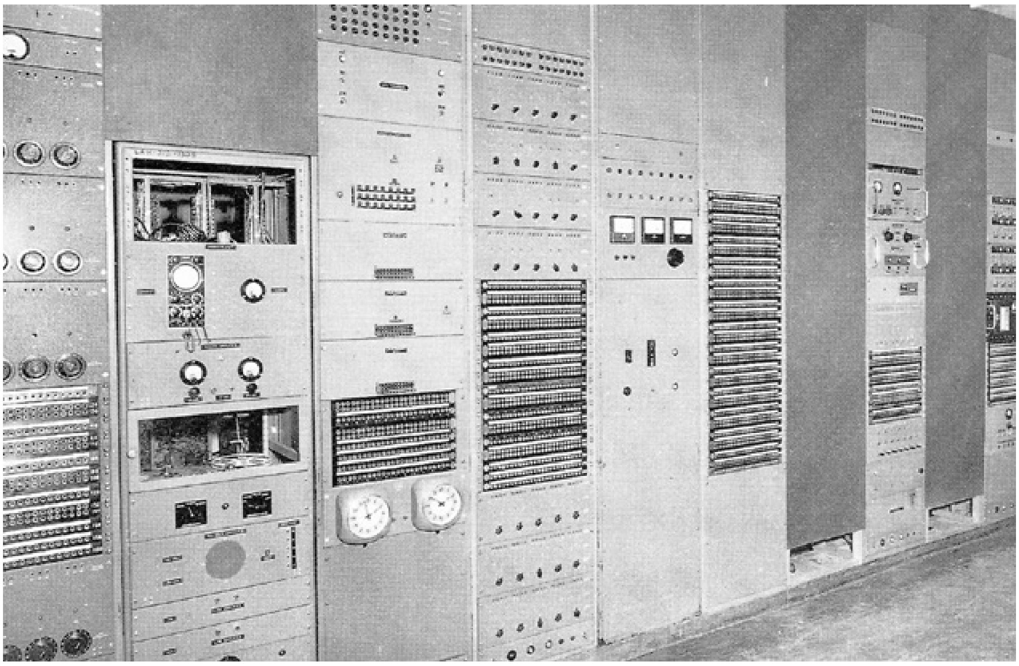
Post CH was the instrumentation site that changed most: by the mid-1950s the last reminders of Orfordness had vanished. The old container body was removed and in the empty space new Mk 2 timing equipment was set up in 1951-52. This was developed by Frost with the help of Brooks and a cheerful Western Australian D. M. Robson, who despite a speech impediment was a gregarious soul with a wide circle of friends. During the next two years Frost designed a completely new installation for CH, which he labelled the Central Timing Equipment (CTE) Mk 3. Considerably more sophisticated than the simple Orfordness timing equipment, it was a universal provider of synchronised timing signals in the simple uncoded form then fashionable.[18] In place of the clunking master control box used to operate the instrumentation was a sequencer which abandoned uniselectors for the better Ericsson crossbar switches.

D. M. Robson, a cheerful member of Frost's instrumentation team.

Moran eventually replaced the old Orfordness chronograph's pen unit with a version which had a two speed gearbox of advanced epicyclic design, with small solenoid operated drum brakes to change speed. This gearbox was one of the first high precision mechanisms to be manufactured in the Salisbury workshops. To go with the improved pen unit Frost designed a new electronic input unit which unlike the Orfordness version used balanced transmission line inputs to overcome crosstalk problems. In his design the brass pen roller on the pen unit could be earthed; formerly it and the conducting backing of the Teledeltos paper had been live and prone to inflict a nasty 500 volt shock on the careless or unwary operator.



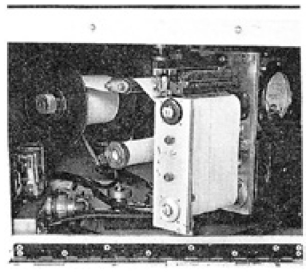
John Duncan operates the post CH timing equipment after the old container body had been removed. The geophone recorder is at the left.



The final MK 3 version of the Range A central timing equipment, developed by Frost, during installation.

This new equipment—CTE Mk 3, crossbar sequencer and chronograph—was installed rack by rack at CH in 1953 and 1954. It proved a little late in the day for Range A1, the extension range then being set up for the Blue Boar trials, as this closed in February 1955 when Blue Boar and Red Rapier were cancelled. However it served Range A well until 1957 when this in turn was closed and all the equipment removed.

What happened to all this lovingly developed Range A instrumentation? Some of it went to the main range (Range E) and was used until it became obsolete, while the remainder was either cannibalised or relegated to junk stores and eventually disposed of. The ground speed cameras were superseded by Contraves kinetheodolites, and apart from the lenses were probably junked too. The longest survivor was the Moran/Frost Mk 4 chronograph. The design was later used at Range E, both in the Instrumentation Building and at all ballistic camera sites. One of these old chronographs is still used at the Range—a museum piece of valve technology from thirty years ago.



The pen unit of the later chronograph, still used in the 1980s.

SETTLING INTO A ROUTINE

In its earliest form the RAE plan for bombing trials in Australia consisted of a development program and a research program. The first was intended to test various sizes and types of bomb from the smallest to 4.5 tonne blockbusters. The research program used only one standard 1000 pound MC bomb (i.e. 450 kilograms 'medium capacity'), but there were to be eighteen variations fitted with various combinations of nose and tail shapes so that their ballistic effects could be compared. Practice bombs would also continue to be dropped for training and proving. All of these bombs would be inert ballistic dummies.

The RAE development program trials began in late July 1949 with the dropping of a 450 kilogram bomb. By the end of the year thirty more had followed, and 215 practice bombs as well. Twelve months later the development program was well under way with a further 115 of the 450 kilogram bombs dropped, and the program continued for another ten years or so, although it was to be transferred to Range E in about 1957. The research program started in early 1952 but had been taken as far as it could with the Lincoln bombers by 1955. The program was extended for a while to take advantage of the greater heights and speeds of the Canberra bomber, but by then the end-point approach to ballistic research had become outmoded, as we will see later.

The bombs used were all of British design and at first were manufactured there and shipped out. Soon, though, in pursuit of the policy that Australian industry should participate in joint project work, contracts were let to Australian firms, such as Perry Engineering in Adelaide and Rubery Owen & Kemsley, for manufacture of bombs and tails. This work was

Right: A huge 4.5 tonne bomb being loaded into a Lincoln bomb bay in the Woomera hangar.

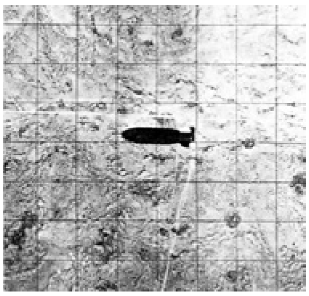
shared with the government munitions factories in Victoria at Maribyrnong and Bendigo and at the Government Aircraft Factory at Fisherman's Bend.

Some of the bombs dropped in the RAE development program were fitted with retractable tail fins which, to save space in the bomb bay, did not flip out until after release. In some early trials of the big 5000 pound High Capacity (HC) bomb the fins were sticking, and this despite modifications in Britain. The mechanism worked perfectly on the ground. After four failures in 1951 Moran took a tail assembly into a RAAF cold chamber at the University of Melbourne and soon found the cause of the trouble. Each fin was attached to a long arm which fitted into a slot in the bomb casing. As the aircraft climbed to a high altitude the exposed black casing contracted more than the arms (which were of a different material) causing them to jam.[19] After this discovery, RAE again modified the design and there were no more problems with flip-out fins that would not flip out.

Peter Moran, one of the four Australians trained at Orfordness.

The early training drops had been held on alternate weeks, but as the program got into full swing there were trials every week. As Hicks recalled it:

> The trials procedure was, when we arrived on Monday, to check all the instruments were OK, load cameras and so on. Then a visit to George Trefry, the meteorologist, for a forecast of the next day's weather. If OK we'd ring Mallala to confirm the bombload, trials conditions, etc. We left the village at 7 a.m. and the aircraft would arrive over range at 8 a.m., having climbed to bombing height on the way. Then it would do a dummy run along the bombing line so that we could measure the ground speed, set the cameras on the release area and mark out the countdown on the plotting table. By this time the aircraft would be back, ready to start a live run. On one occasion the pilot called 'turning on for dummy run' and we waited a while, but the plotting table pen was quite stationary, although the aircraft should have been doing about 200 knots. Panic checking of radar, plotting table etc.—all OK. Call aircraft—'on bombing run'—still no movement. Kine operators could see the aircraft apparently stationary. It was our first experience of what the Met people call a 'jet stream'. Of course, we had to bring the aircraft down to a lower height and carry out the trial from there. The normal weather pattern at Woomera is for a sunny early morning, cloud building up at about 10 a.m. and clearing about 3 p.m., so we'd try to fit in two trials a day—one early, one late. If there was a crash programme on, we could get two aircraft up in series and do four trials on Tuesday, Wednesday, Thursday and two on Friday morning. The film would go down to Salisbury for processing on any available transport aircraft and we'd take Friday's down with us. On our way back, the aircraft landed at Mallala and cars or buses would take us to Salisbury and Adelaide. We often called at Two Wells for refreshment, getting the pub to open up for 'bona fide travellers' as we'd travelled more than the statutory 60 miles (pubs closed at 6 p.m. in those days)![20]



An aerial camera shot of a bomb shortly after release from the bomber aircraft.

In the early years a mixed team operated the instrumentation on Range A. Smooker's section at Woomera supplied Army lads to operate radars and kinetheodolites, RAAF mechanics to load the Vinten high speed cameras and an RAN Petty Officer, Greg Sharp, to take care of CH. They were augmented by a team of civilians from Salisbury: Bert Young to

Mary Whitehead [left] and three of her Computers, ready for work on Range A, Pat Davies (second from left) operated a camera obscura.

control the trials, and the instrumentation experts to make sure it all worked and to fix it if it didn't. They all flew up on Monday morning, strapped uncomfortably into the hard side-saddle seats of the Dakota transport. Then back to Adelaide on Friday, often only to return the following Monday on what was soon known as the 'yo-yo' trip. The 'Computers' (computer operators) went up as well to operate the Askania kinetheodolites mostly, but one of them, Pat Davies, also took on a camera obscura, one of the oldest kinds of optical instrument. The one at Range A was a tall van on large rubber tires, looking something like an old gypsy caravan, and it was placed on the centre line road under the bomb release point:

> I suppose when I used to go up on trials I was always glad that no one could see me climb up to the top of the damn thing and take the cover off the lens, because I was always white when I got up there and whiter when I got back . . . We used it for working out wind speeds during trial times, i had a big plotting table which gave a picture of the clouds and then I instructed the aircraft, spoke direct on the radio to the aircraft and gave them release times for firing smoke puffs at particular heights . . . and I plotted these for speed and direction. You had a big sheet of white paper and you just marked these puffs. Every ten seconds or so. I was quite busy for a very short space of time, but most of the time I just sat and listened to the radio . . . [21]

The bombs were dropped by RAAF crews of the Experimental Flight, a detachment of the Aircraft Research and Development Unit (ARDU). For these early trials this Flight was based at Mallala, using the three modified and two standard Lincoln aircraft.[22] In late 1949 a Mustang fighter aircraft was added, and its job was to fly alongside the Lincoln and photograph the bomb as it emerged from the bomb bay. Dropping heights ranged from 5000 feet to 32 000 feet, and the higher the altitude the more uncomfortable the conditions were for the crew. The Lincoln's heating system was poor and despite the thickest clothes everyone got frozen stiff until electrically heated flying suits were introduced. The planes were unpressurised and the oxygen system did not have enough safety margin to cover flights lasting five hours, most of it spent higher above the earth than the summit of Everest. Several trials had to be aborted because a crew member was suffering from oxygen deficiency.

In one dramatic incident at 32 000 feet, the navigator went aft to check the recording camera after attaching a long extension line between his helmet and the oxygen supply. When he had not returned after five minutes, the skipper sent his wireless operator back, also on an extension line, to see what was up. Another five minutes passed and neither returned. Without more ado the skipper put the cumbersome Lincoln into a screaming power dive. With rivets popping from the airframe like shotgun pellets, the plane dropped like a brick to 10 000 feet where the pilot levelled out, switched to automatic pilot and rushed aft to find both crewmen sprawled unconscious. He got them back on oxygen, then went into a rough landing at Woomera. The undercarriage was damaged and the engine heads warped, but the pilot's quick action had certainly saved two lives.[23]

The Experimental Flight shifted its base from Mallala to Woomera in the middle of 1950. The move shortened trials times and raised the operational ceiling from 32 000 to almost 35 000 feet as less fuel had to be carried. By November 1952 the Flight had a fleet of eight Lincolns, including two 'specials' in which two of the normal Merlin engines had been replaced by Armstrong-Siddeley Python turboprops, each four times as powerful as a Merlin. Earlier that year the first jet bomber had been added to the fleet. It was the English Electric Canberra, which despite its name originated in Britain although Canberras were later built in Australia and used by the RAAF for some years. The Canberra was pressurised and could fly higher and faster than the Lincoln, so when it was not needed for Blue Boar (for which it had been acquired) it was pressed into service for bombs work. Indeed, this Canberra (A84-2) was greatly in demand for various services,. not all of them licit. On one occasion lack Redpath of the Blue Boar team went into the Technical Area hangar and found his precious Canberra sitting on wooden blocks. The London to Christchurch air race was on then, and a competitor had come in from Perth to refuel. His plane had oleo trouble, so A84-2 had been cannibalised to do a quick repair. Another time the Canberra was sent all the way up to Darwin to collect an RAAF officer—who was needed as a pianist at a senior mess party. Darwin was at the extreme limit of the Canberra's range, and it landed back at Woomera with the fuel tanks so empty that it had to be left at the end of the strip. Not a drop remained to taxi in.

In 1955 a second Canberra and a Vickers Valiant were added, and from this time the jet bombers gradually took over. By the end of 1957 some of the Lincolns had been written off after gale damage or crashes, and the rest scrapped as obsolete. One ended its days ignominiously in a rubbish pit half-way between the village and the Technical Area which has since been filled in.

DATA REDUCTION, ANALYSIS AND REPORTING

The data produced during the bomb trials took diverse forms, and the output of each instrument had its peculiarities: there were plates from the ground speed cameras holding images of landing lamps and smoke puffs, long rolls of marked paper from the chronograph, films from the kinetheodolites and the aircraft cameras, records from the geophones. Working on these clumsy records was a very painstaking task for the Computers. Most demanding of all was the astronomical calibration of the ground speed cameras. First they identified dozens of stars on each plate with the help of catalogues and almanacs. Then they fixed the co-ordinates and determined the azimuth and elevation of each star as it tracked across the plate. This involved microscopic inspection of the plate and measurements with a tolerance of better than one hundredth of a millimetre. The whole process took two of them six weeks for each of the two plates inside the camera. There followed much 'number crunching' to solve nine monstrous equations and finally the application of corrections to adjust for distortion in the lenses and other mysterious anomalies. Sometimes they had no sooner finished than the news came in that the camera air-conditioning had broken down, and the process had to start all over again. Still, the Computers were young and keen and ran competitions to see who could complete the calculations in the shortest time.

The analysis of the trials themselves was rarely a routine matter. They were expensive to conduct and every drop of information had to be squeezed out of each one. Ideally, each trial was supposed to produce three ballistic indices[24], but despite hours spent scrutinising imperfect cine film taken from the bomb bay, another aircraft or the ground, sometimes only one index could be determined. The star performer in this business was Win Lloyd, a very experienced analyst on exchange from RAE, who was famous for her rigour and could extract more sound information from a set of records than could ordinary mortals. By 1954 her work had led to the formulation of a 'Lloyd's Law', and tables based on it allowed the reconstruction of the complete trajectory of a bomb with much greater accuracy, thus reducing the size of trials programs.

The final step after all this painstaking reduction and analysis was to write a report for each series of trials. More than eighty such Ballistic Trials (B/T) reports were written in the 1950s. In these modest documents were crystallised the efforts of dozens of people, not only the data analysts but the range operations, air crew and instrumentation teams as well. The B/T reports were immediately passed to Britain and became the basic data for setting the aim of that particular bomb type.

REORGANISATION AND INTEGRATION

The early years of bomb ballistics in Australia were the 'Hicks years', for it was he who planned Range A and its extension A1 and who had formed and led the team that became Bomb Ballistics Group. By early 1952 Hicks had served his term and wanted to move back to Britain. With his mathematical background, his appreciation of instrumentation, his quiet but strong personality and his ability to mix readily with his staff at all levels, he had succeeded in building up an effective team, a self-contained unit which with close support from the RAAF flying unit and the range operation and maintenance staff was able to cover all aspects of bomb ballistics.

Fortunately an obvious replacement was available from Britain. J. S. Price had spent some time during the war at Orfordness working under Hicks, and after a period at RAE organising early LOPGAP (RTV1) rocket trials at Aberporth he had replaced Frame in 1950 as a Principal Scientific Officer in charge of Orfordness. Price agreed to come to Australia at the same level to take over Bomb Ballistics Group, and he arrived in 1952.

I. S. Price who replaced Hicks.

James Stanley Price, who was to retain a close interest in joint project activities for the rest of his career, was widely referred to as 'Jim Price' at home and 'Stan Price' at work. He was not steeped in ballistic mathematics to the same extent as Hicks. Rather he was a broad thinker who knew his limitations and was ready to delegate to others what he could not do himself. Because of this and his frank, honest but patient approach tinged with more than a hint of cynicism, he got on very well with his staff.[25]

In June 1953 the small empire that Price had inherited from Hicks was split into two groups: Air Projects (led by Price) and Air Instrumentation (led by a promoted Bosher). While Price thus lost Instrumentation, he was given control of all aircraft trials including the air trials section of the old Trials Co-ordination Group, which were planning development trials of Pika and Jindivik and aircraft flights for air-launched missiles and forthcoming interception trials.

This 1953 reorganisation maintained the split between 'missile' and 'air' activities—in fact the titles Air Projects (AP) and Air Instrumentation (AI) were exactly paralleled by the Missile Projects (MP) and Missile Instrumentation (MI) groups that were created at the same time. All were part of a new Trials Division headed by the redoubtable Boswell. But within two years this split of functions changed. Both the air and the missile sides were integrated in the 1955 reorganisation that in a sense marked the coming of age of the joint project. The two 'Air' groups disappeared: AP Group was absorbed into MP Group which retained its name. AI and MI Groups were thrown into a melting pot and then recast into three instrumentation groups in a new Range Development division. In May 1955 Boswell was promoted and Price stepped into his shoes as Superintendent of Trials Division, which covered planning, execution and data reduction of all trials whether air or missile—his division now included the range operation and maintenance staff in a new Ranges Group at Woomera as well as Mathematical Services Group. With minor changes this organisation remained until 1968.

With the organisation integrated the next logical step was to integrate the ranges. Apart from the small VT fuze dropping area known as Range B, which was to close in February 1956, only two ranges remained in 1955: the main Range E and Range A which was used for all bomb ballistics trials. But Range A had to be retained for the time being as it was equipped with specialised ground speed cameras and radar to control the aircraft track. Further, both ranges had a busy trials program.

One factor which contributed to the final integration was a growing disenchantment with the classical end-point ballistics approach for which Range A had been designed. This approach was intended only to give immediate bomb-aiming data, but even here it often raised more problems than it solved.[26] With the new jet bombers flying faster and higher than before, their bombs would be falling for long periods at trans-sonic speeds where little was known about the high drag to be expected. More fundamental data was needed on the drag of different bomb shapes in this region, on what happens to drag when the bomb oscillates during free flight, and also on the effect on bomb release of turbulence in the bomb bay.

One approach to measuring drag was already in full swing; it started from a British request in 1951. This was a program of model bomb firings which were not drops from aircraft but rocket firings from the ground. Scale models of various bombs, about half size, were constructed of sheet metal around standard solid propellant motors and were weighted to simulate the dynamics of the bomb. These rocket bombs, which were not of course intended as weapons, were fired on the missile range—initially Range G—and their trajectories recorded by kinetheodolites and doppler instrumentation. The aim was to determine the drag coefficients of particular shapes by measuring the rate at which the atmosphere slowed the models down through trans-sonic velocities after the rocket motor finished thrusting. Some models were deliberately disturbed during flight by small lateral rocket motors known as bonkers, so that the effect of the resulting oscillations on drag could be measured. This model bomb program was at first led by Moran but afterwards handed over to R. L. Brooks of Aerodynamics Division, and it was to continue at intervals until late 1959. But it was never seen as the complete answer to bomb drag effects. Like any model approach it would have to be validated, which would require free-fall drops of full size bombs, and these would be needed anyway to investigate bomb bay release turbulence.

Dr Gordon Richards, the UK ballistics expert.

In February 1955 a small team from RAE Armaments Department visited Salisbury to discuss future bomb ballistics trials. Its leader was no stranger: Hunwicks was revisiting what he had helped establish as one of the original Evetts eleven. A key member of the team was ballistics expert Dr G. R. Richards, who had long discussions with Price and Watson on how best to tackle the problem. They decided that end-point trials would continue to be used to accumulate bomb-aiming data, but possible ways of measuring drag and bomb disturbances would also be pursued. As well as the model bomb trials, every attempt would be made in free-fall trials to improve the measurement of trajectories so that acceleration could be derived, and also to use telemetry to record acceleration and bomb disturbances directly.

Hunwicks was well aware that taking these new measurements was not just an academic exercise in applied physics. Some of the new techniques would take time to develop, but an immediate improvement would be needed for a new and very important series of bomb trials, which was in fact the real reason for his visit. The bomb in question was referred to simply as the '10 000 lb MC' but it was actually a ballistic dummy of Blue Danube.[27] The romantic Viennese aroma hanging around this code-name was perhaps someone's black joke, for Blue Danube was in fact Britain's first atom bomb. The warhead from Blue Danube had already been tested at the Monte Bello Islands on 2 October 1952 and further detonations of related fission devices followed at Emu and Maralinga, but Woomera and the joint project were only peripherally involved in these. At the Range only inert ballistic dummies of nuclear bombs were ever dropped.

Hunwicks briefed Boswell on the real nature of the trials. Few others were told, although they may have guessed from the elaborate security precautions. These called for all the debris to be collected from the range after impact, and only those with a 'need to know' were allowed to look at the bombs even from the outside. They were carefully shrouded as they were loaded into the bomb bays.

That August a gleaming new swept-wing aircraft created a stir as it touched down at Woomera airstrip. It was the Vickers Valiant four-jet bomber, recently delivered to the

Britain's first 'atom bomber' squadron of Valiants at RAF Gaydon in March 1956. (Topham)

RAF as the first of the V-bombers which would be carrying Britain's nuclear weapons.[28] Its performance matched its appearance; for on this, its maiden flight to Australia, it had covered the distance in a dazzling twenty-one flying hours, breaking several records.

The Valiant could not drop its bombs on Range E, because that had only Askania kinetheodolites to fix the release points, which were no match for ground speed cameras. So the decision was to stick to Range A, which also had Askanias, but to try to improve the instrumentation used to measure drag and bomb behaviour. When the Valiant dropped the first of the thirty-six Blue Danube dummies on Range A in September 1955, an airborne camera photographed its behaviour during release, and tracking cameras on the ground attempted to record what happened to the bomb during its long drop to the ground. A simple reflection doppler had also been installed in the target area in an attempt to measure bomb velocity, but unfortunately it proved of little value because the reflection from the bomb was swamped by that from the aircraft.[29]

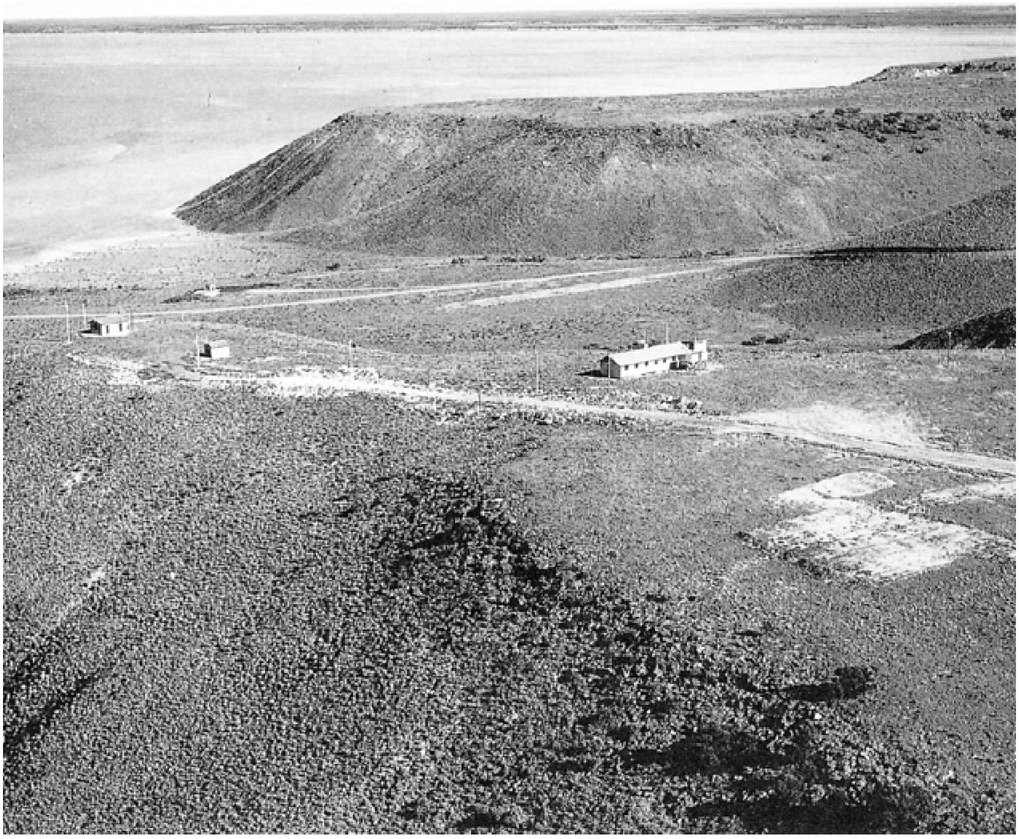
One of the bombs dropped in these trials showed all the signs of instability in flight, and it was suspected that the flip-out fin mechanism had failed. As the trials were urgent, the Askania kinetheodolite records were rushed to Britain 'by hand of BOAC pilot', and Hunwicks went personally to Heathrow airport one Saturday morning to meet the aircraft. He closely examined the films and satisfied himself that the flip-out mechanism had worked properly, but nobody could suggest how the fins could have failed after flipping out. Meanwhile all the debris had been returned to Britain on the Hastings ferry service. RAE's Accident Investigation Section was called in—they were the people who had solved the catastrophic metal fatigue problem in the Comet I. They carefully examined the kinetheodolite films and spotted a tiny clue. After inspecting the wreckage they came up with the answer: a small door in the tail used for pre-flight preparation had come open, ripped off and damaged the fins. The solution was a better fastening and a more rigorous inspection. Without such a quick response and co-operation across the world, this problem in a top priority project would certainly have been much more serious.

Win Lloyd and her Computers struggled valiantly to extract drag data from the Askania records of these '10 000 pound MC bomb' trials, but when the next dummy nuclear bomb was tested it was on Range E which by then was equipped with the new Contraves kinetheodolites as well as the existing doppler and telemetry systems. Ron Buller, head of Ranges Group at Woomera, had by now persuaded Price that Contraves records over the whole drop would give a better measure of bomb ballistics than the classical end-point approach. So in November 1956 Contraves provided the main optical records for a full scale bombing trial on Range E for the first time. The bomb dropped by the same Valiant WP209 was known as the '7000 pound MC', and although this suggests it was smaller than the Blue Danube bomb it was in fact a dummy of Britain's more powerful megaton size bomb, codenamed Yellow Sun. The following February trials of a third deterrent bomb commenced. This was a dummy of a bomb known as Red Beard, developed for use by the Royal Navy as well as the RAF. Its local code-name was '2000 pound TM' which was a deliberate misnomer intended to suggest a target marker bomb. Although the weapon packed about the same punch as Blue Danube, it was much smaller—small enough for the dummy to be carried by a Canberra. The first trials were on Range A, but they were soon transferred to Range E with its superior instrumentation for trajectory cover.

Ron Buller, head of Ranges Group at Woomera.

The final decision to integrate the two ranges came in mid-1956. The Department of Air wanted to withdraw half of the RAAF ground staff at Woomera, and Boswell accepted Price's recommendation that rather than training new recruits to replace them, all the bombing trials should be moved progressively to Range E. The new Contraves network there was almost as accurate as the ground speed cameras for end-point ballistics, and it already had in place radar navigation and plotting displays put in to handle Jindivik interceptions and trials of air-launched rockets such as Blue Sky. The last bomb fell on Range A in mid-1957, and it then closed. Thus ended the separateness of bomb ballistics; after this, all trials were handled by one organisation and one Range.

Bomb ballistics work continued intermittently on Range E for the rest of the project. The nuclear bomb program was completed by 1960, but there were other conventional bomb trials in the early sixties. Attention then turned to dispersion trials of cluster bombs, in which hundreds of small inert or live anti-personnel bomblets were scattered from a canister released at low altitude. One such project was the Australian Karinga and, although Karinga was later abandoned, trials of it were still underway when the project ended in 1980.



The VT fuze range (Range B) showing the observation hut (right) and camera post on the northern cliffs of Lake Hart.

VT FUZE TRIALS

Fuzes in weapons are the devices which detonate the explosive charges of shells, mines, bombs and missile warheads.[30] Before World War II, fuzes, except for those of mines, were simple percussive or mechanical devices which worked at a set time after firing, on impact, or a set time after impact. But in 1940 a much more sophisticated type of fuze was pioneered in Britain and then perfected and manufactured in the United States. This was the radio proximity fuze, known in Britain as the VT fuze. ('VT' stood for 'variable time': a deliberate misnomer to conceal its operating principle.) Put simply, the VT fuze worked by sending out a continuous radar signal from the shell, rocket or bomb carrying it. When it sensed the proximity of the target or ground from the nature of the echo picked up by a receiver, it triggered the charge. It was Butement who first came up with this idea and, together with a colleague, L. S. Shire, explained how the doppler effect could be used for this purpose. The new fuze greatly improved the efficiency of anti-aircraft rockets or shells by exploding them at the closest point to the target, and of bombs or shells by causing them to detonate above ground where blast or shrapnel would be most effective. Butement's VT fuze ranked with radar, jet propulsion and the atomic bomb as an outstanding allied forces secret weapon. It helped, for example, to repulse the VI flying bomb attack on Britain in 1944.[31]

At the time when the 'Bible' was being prepared in 1946 the Armaments Department of RAE had developed its own VT fuze for bombs, and 30 000 of them were being made under contract by the Gramophone Company at Hayes near London. One purpose of the contract was to gain experience in the mass production of these small electronic devices, and the fuzes produced were not going to be used operationally but in experiments to test their performance. As the manufacturing run proceeded, samples were being tested in inert bombs by dropping them over sea ranges off the Scottish coast, but again the climate was a problem. Quick results were necessary if faults were to be spotted in time; the production run could not be held up for weeks on end waiting for clear weather. The work was ideal for Woomera and accordingly the 'Bible' specified that VT fuze trials would be held in one corner of Hicks's bombing range. It was to be a busy corner, with perhaps a thousand or more bombs dropped in it each year.

RAE's VT fuze was designed to detonate its bomb at a preset height. In Scotland the performance of the fuze was monitored by dropping an inert bomb into a target area out

A victim of Lake Hart's treacherous salt crust, hiding thick mud underneath.

at sea. The fuze detonated a smoke puff in the bomb, and a camera on the shore recorded both the smoke puff and the splash of the bomb into the water below it. Two theodolites on the shore fixed the position of the splash, and the exact height of the burst above could be scaled off from the photographic record. A receiver picked up and recorded the radio signal emitted by the fuze.

The RAE expert in charge of these trials was F. H. (Fred) East, and when the call came for him to go to Woomera in July 1948 to continue his work he brought his Scottish gear with him. When he arrived a temporary range had already been set up for the purpose at Shell Lagoon at the edge of the bomb ballistics range. Shell Lagoon was normally a dry saltpan but at this time was full of water, making it an ideal surface for bouncing back the fuzes' radio signals. At the Lagoon on 7 and 9 September 1948 East did his calibration trials. He did not attempt to measure the height of fuze functioning. Thirty-four '500 pound MC' bombs were dropped; bombs supplied from Australian war surplus stocks and prepared by having their explosive filling steamed out and replaced with sand. These Shell Lagoon trials were only the second series to be held at Woomera, and were conducted in a very similar fashion to the parachute trials of the previous December and January, even to using the same Lincoln bomber flown up from Mallala.

F. H. East, the RAE expert on VT fuze trials.

Shell Lagoon could only be a temporary expedient, for its water was evaporating quickly and its bed was full of rocky outcrops. Before leaving Australia for home, East had a look at the much larger Lake Hart. This also was drying out, but East made inquiries and discovered that the bed was always coated with a thick smooth crust over saline mud—as a few over-adventurous drivers later discovered to their cost—which would make a reflecting surface as good as water. He chose a target area on the northern part of the lake and a place for the instrumentation posts on the overlooking cliffs, and left the supervision of the work to Bonnell.

The facilities at Lake Hart for Range B (as it was named) were simple enough; target markers on the saltpan, a graded access track, a camera post and a small observation hut with plate glass windows to house the receiver of the fuze signals and the gramophone disc recorder, and basic living quarters for six. It was very modest compared to what arose nearby almost twenty years later, when the same cliffs echoed to the thunder of Europa, the great three stage satellite launcher.

When East arrived from England on his second visit he inspected and accepted the new Range B installations, and the second series of trials followed on from 2 to 7 May 1949: fifty-nine bombs were dropped, thirty-nine of them from a height of 20 000 feet (6 kilometres). Of the latter bombs, about half fell outside the field of view of the cine camera, and five of them dropped beyond the target area altogether. The Trials Officer report, signed by Brigadier Neylan who was Range Superintendent, reported acidly that

> most of the bombing was carried out above cloud, which varied in intensity from two to five-eighths. Due to the 'press on' spirit of the Scientific Party, and the willingness of the aircrew to oblige, many bombs were dropped in unfavourable conditions . . . It must be said that the significance of these incidents appeared to cause more concern to service personnel than the Scientific Party.[32]

The eventual solution was to double the range scale of the radar at Range A so that it could also control aircraft flying over Lake Hart.

After this baptism Range B lay unused for nearly four years. RAE had struck trouble in producing its VT fuzes; troubles both financial and technical, both of which were to be a common story in the years ahead. Proposals for fuze functioning trials were revived in 1952 and to them were added two new series. One was of a series of trials of bombs designed to dispense poisonous mustard gas (really a volatile liquid), in case later policy was to have bombs charged with this agent brought into service. Such bombs, if exploded above the ground by a VT fuze, would spread their poison over a wide area. But what was the optimum height for the burst? To answer this question the Woomera trials were to use bombs filled with a harmless liquid dye which would scatter over the saltpan when the bomb exploded in mid-air, giving a pattern of dispersion that could be measured by ground survey and air photography. The other series was more dramatic, for it was planned to use large live conventional bombs set to explode in the air so their blast pressures could be measured at various points on the ground. The fuze trials needed some extra equipment, including cameras to measure the burst height and radio gear to record the fuze transmission and to communicate with the aircraft and the radar at Range A.

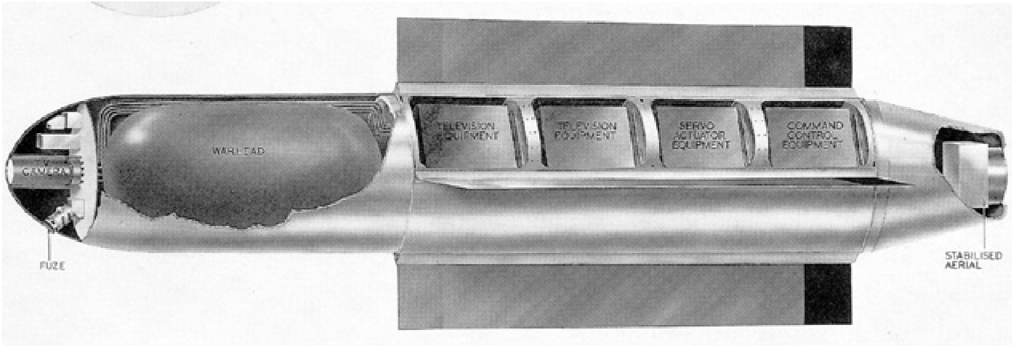
RAE asked that an Australian officer should be sent to Britain to study the trials proposals in detail, so that he could relieve East. For this role Hicks selected C. N. (Norm) Gerrard, a quiet conscientious man who had worked on radio and radar in Bosher's instrumentation section of Bomb Ballistics Group. He duly spent some months with East at RAE and then returned to take over the scientific direction of the VT fuze trials.

The blast trials came to nothing, for they were cancelled late in 1953 having fallen victim to general cuts in British defence spending; but the dispersion trials did go ahead on Lake Hart. Early in 1954 thirty-one of the imitation mustard 'dye bombs' fell on the saltpan, followed by air photography and a ground party which examined the area after each drop before the scatter pattern of the fast fading pink dye was lost.[33]

The VT fuze functioning trials finally got underway in earnest in May 1953 and ran until February 1956 when the production run finished. During these years 1484 two hundred kilogram bombs fell to pockmark the target area on Lake Hart. Before they were over the trials had become a very routine business, for only a few people and simple instruments were involved. After that Range B was abandoned. The site lay in peace until the heavy excavating equipment arrived to build the foundations for the great concrete emplacements of Blue Streak.

BLUE BOAR AND RED RAPIER

Blue Boar was a guided but unpowered bomb, developed in the early 1950s with the idea of increasing the accuracy of bombing from high altitudes. Physically, Blue Boar was a conventional cigar shape with stubby flip-out fins. On their rear edges the fins had small control surfaces like an aeroplane's, operated by compressed air from a bottle. Shortly after release an autopilot in the bomb took control and directed it downwards into its glide path. Meanwhile, a television camera in the nose relayed a picture of the approaching ground back to the bomb aimer, who steered it on to target via a radio link. The aim was to pinpoint the target within 100 metres by this means. The advantage, in theory at least, was that Blue Boar could be dropped in totally obscuring cloud, providing the cloud base was at least 3 kilometres above the ground. The idea of such a guided bomb was not new. During World War II the Germans used a glider bomb, FX1400, which was guided visually from the bomber by radio control, and one of these sank the Italian battleship *Roma*. The Germans had also experimented with television guidance.



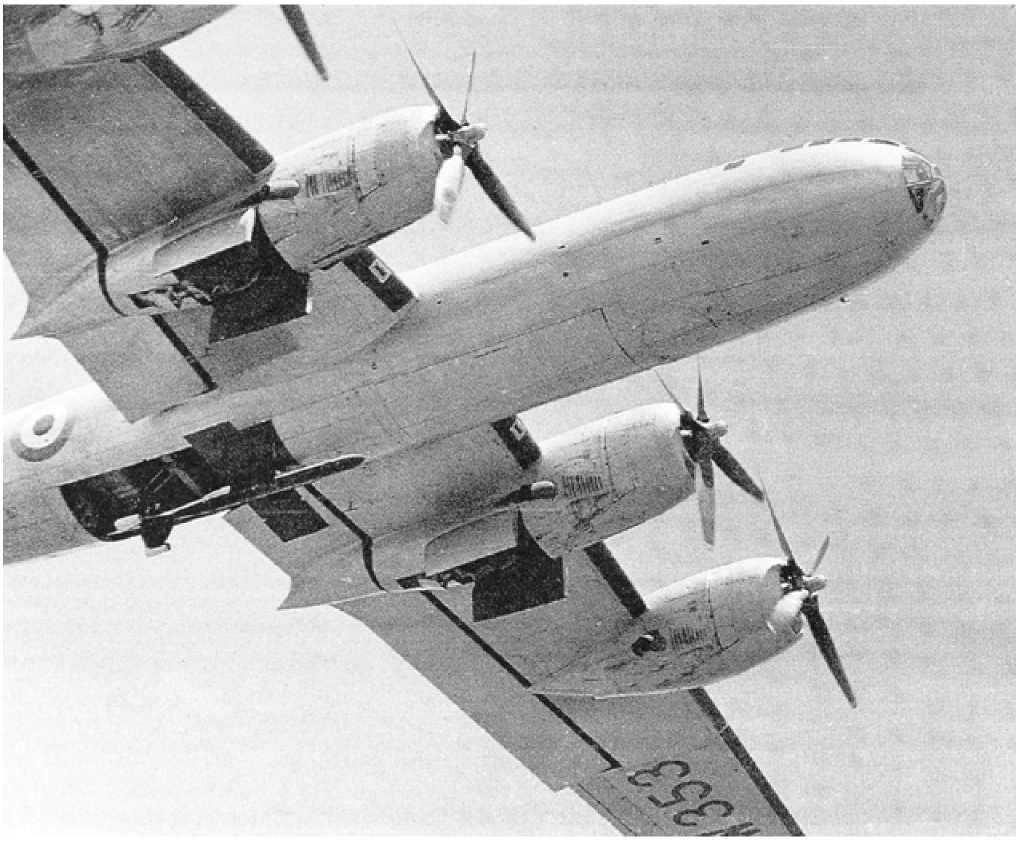
An artist's impression of the Blue Boar glider bomb, which was to be guided to its target by means of a TV camera in the nose relaying a picture of the ground to the bomb aimer in the aircraft. The project was cancelled after early trials at Woomera in 1952–54. (RAE).

The British-controlled bomb project, which had appeared in the 'Bible', was by no means a sideshow like the parachute and VT fuze trials. In 1947 Tizard's Defence Research Policy Committee had put it on a select list of only four top priority guided weapons projects.[34] At that time it was an open question whether the controlled bomb should use radar guidance which would work through cloud, or a clear weather television system. But efficient radar guidance seemed some years away, and by late 1949 contracts had been let to Vickers and EMI to develop the television version, by now christened Blue Boar.

When a team from Vickers, EMI and RAE arrived in Australia early in 1951 to discuss Blue Boar's requirements, the first task was to find a suitable range. The target area needed to be surrounded by some natural features to be used as a guide to steer the bomb on to target, and a suitable area was chosen just west of Shell Lagoon and next to Range A whose radar tracking and timing equipment would be used. Hicks planned the layout of this new range, which became known as Range A1. It needed a target, four spotting towers (S4 to S7) from which the impact point could be triangulated, a line of five kinetheodolite posts (K1 to K5), and a Vinten high speed camera to track the aircraft and the bomb from release. A receiving station for the telemetry and the television signals was eventually provided not at Range A1 but at Range E. By late 1951 the Board of Management had approved expenditure for construction of these facilities. Much of the equipment—bombs, telemetry, television gear—came from Britain, and the Ministry of Supply retained tight control over Blue Boar (or, as Security required it to be called, Project G). The British also supplied an RAF officer, Flight Lieutenant T. A. Roberts, as Blue Boar project officer. He was a tireless and articulate administrator who convened innumerable progress meetings in which the contractors' representatives like I. H. Redpath of Vickers confronted the LRWE men who had to prepare Range A1. One lasting outcome of the resulting dashes backwards and forwards across the world by the contractor and Ministry staff was the regular fortnightly United Kingdom-Australia air service, which operated for most of the joint project and has been described more fully in Chapter 9.

By June 1952 Range A1 had been mostly instrumented and preliminary trials were in progress using ordinary bombs as well as dummy Blue Boar vehicles to check out the telemetry senders and the ground receiving station. It proved necessary to set up a new radar control post at Red Lake, as Post R was not suitable for Blue Boar trials. Later in the year there were developmental trials with a small 450 kilogram practice bomb to test the guidance, command, telemetry and autopilot systems. There were also attempts to recover by parachute a cine camera mounted on a freefalling bomb. By the end of 1954 some sixty-nine bombs had been dropped on Range A1. But by then the blow had fallen: at the CUKAC meeting of August 1954 it emerged that the British Air Staff no longer wanted the weapon. In fact they had never been very enthusiastic about Blue Boar. Although it could be launched in cloud the bomb aimer still had to have it within 2.5 kilometres of the target before starting guidance. In any case, the aimer could probably only have homed it on to very defined targets unless he was very skilled. All in all, the Air Staff thought there would be rather few opportunities to use Blue Boar. They had accepted it in 1946 as an interim weapon, but as the threat of immediate war receded funds for weapons R&D had been cut and what remained could not be squandered on weapons of limited use. Further, radar guidance systems which could work in all weathers were now practicable.

At the August 1954 CUKAC meeting Australia accepted the cancellation without demur and agreed that the last remaining bombs would be dropped to obtain some



A Washington bomber takes off with a Red Rapier slung underneath, ready for dropping over Range A1.

aerodynamic data for another forthcoming project, called Green Cheese. This was to be a naval anti-ship missile with a radar homing head and sustainer motor, designed to be launched from the anti-submarine Fairey Gannet or the Avro Shackleton maritime bomber. Green Cheese was also cancelled in 1955, after another six drops from a Washington heavy bomber (the RAF name for the US Boeing B29 Superfortress) over Range E. One reason behind these cancellations was probably the forthcoming Blue Steel weapon: a medium range air-to-surface cruise missile fitted with unjammable inertial navigation and capable of stand-off bombing from a safe distance clear of enemy missile defences.

From the middle of 1953 until late in 1954 Blue Boar shared Range A1 with a another project. The old idea of a long range bombardment weapon had survived many vicissitudes and had at last hardened into a definite project called Red Rapier. Red Rapier was to be a big 13.4 metre flying bomb launched from a catapult. It would have had a wingspan of 10 metres, a warhead (presumably nuclear) of 5000 pounds, and three Rolls-Royce SOAR engines. It should not be confused with the later Rapier mobile missile/launcher system.

The development of Red Rapier was also in the hands of Vickers, who were working to a MoS specification. Vickers began by building at their Weybridge plant a number of unpowered one-third scale models. Twelve of these—they looked like big model aeroplanes—were dropped over Range Al from a Washington bomber. They were programmed to do certain manoeuvres to gain aerodynamic data and to test the automatic pilot for the full-sized aircraft. The recovery phase was under radio control. A cluster of three parachutes deployed and a nose weight and the wings separated to fall free to the ground. On one trial the radio command for recovery was accidentally transmitted while the model was still in the Washington's bomb bay. The parachutes deployed with a shock that nearly threw the pilot through the windscreen, and then tore themselves to shreds and wrapped around the tailplane. The nose weight was thrown clear and almost hit an observing Mustang nearby. After this mishap and the rest of the uneventful model trials, Range Al closed for good.

The intention was to flight test Red Rapier on Range E in 1955. This would have made it a very influential project because, years before it actually happened, the Range would have needed extension out to 500 kilometres and the observation posts installed down its flanks just as the original plans dictated. But it was not to be: in September 1954 all work on Red Rapier stopped and formal cancellation followed early in 1955. This kind of weapon was by now considered too slow and short in range, too inaccurate to risk using nuclear warheads, and too easily shot down by the rapidly evolving guided missiles. It was the end of the line for the long range flying bomb or pilotless bomber, until the concept was reborn with the advanced terrain-following cruise missile of a later era. British interest was now switching to the ballistic missile, and in particular to its own intermediate range ballistic missile—Blue Streak.

While the almost simultaneous cancellations of Blue Boar and Red Rapier were not the first Australian experiences of the British stop-go approach to projects—after all, memories of the Range cancellation scare of 1947 were still fairly fresh among the few who knew of it—they were the first that were widely known at the working level, and the first cancellations of large projects in full swing at Woomera. It was also significant that the decision had in both cases been a unilateral one: Australia was kept informed but, as far as is known, not consulted beforehand. In this sense Blue Boar and Red Rapier foreshadowed the much more traumatic Blue Streak cancellation some five years later.

Notes and Sources

1. 'Ballistically identical' means with the same exterior shape and surface and the same mass, centre of gravity position and moments of inertia as the live bomb.
2. 'Appreciation of the work to be carried out in constructing the Guided Missiles Range in Australia' (January 1947): Memorandum No 3.
3. ORS dated back to 1930 when bombing trials began with some very basic equipment: stopwatches, binoculars and a camera obscura which was probably the only building on the site. RAE withdrew in May 1958 whereupon ORS was used by the Atomic Weapons Research Establishment for about twelve years. Later the site was cleared and it is now a nature reserve.
4. 'Appreciation of the work . . .' Specific Appendices No. 4 & 5.
5. Folders LRWO(A)/BB/2 parts 1 & 2, 1946-47.
6. P.V. Moran 'Ground Speed Cameras Bomb Ballistic Range Woomera.' LRWE Instruction Manual No. IM 52/2 (May 1952). DRCS Library ref SWM38279U. The lens system had to cover a wide angle yet be long enough in focal length to give the magnification needed for accurate reading. There was considerable consultation with the optical firm of Wray on the coverage that could be squeezed from a high quality lens of this type, but in the end a compromise using one lens was found impossible, which led to the dual camera design. Even so, the 1500 mm wide angle Wray lenses were specially designed. In the focal plane of each lens was a long but narrow glass graticule plate, its lower surface ruled into squares which were star calibrated. The two plates were aligned along the aircraft track and were covered by a single lightweight wing shaped focal plane shutter, which reciprocated to and fro to give multiple exposures each of a thousandth of a second. There was also a separate capping shutter above each lens to select the desired sequence of exposures, usually eleven in all, at one second intervals. In a magazine below one of the graticule plates was the film, held in contact with the glass during exposure. The magazine thus covered only a small part of one plate: it was positioned beforehand to the expected release point by running it up or down rails extending the whole length of both plates. As the camera was designed to hold its calibration for a year or so, it could not be trained on the right part of the sky like the ballistic cameras used at Woomera ten years later (which had to be star calibrated every time they were used), and so the magazine was trained instead.
7. J. M. R. Frost, 'Interim report: control and monitoring equipment for Australian Bomb Ballistic Range' (August 1948).
8. Contribution from S. A. Hunwicks in 1984.
9. Letter dated 26 June 1947 from GWRD(6) to LRWO(A) Melbourne. Transcript on file SA5004.
10. Contribution from R. P. Bonnell in 1983.
11. Contribution from S. B. Jackson in 1979.
12. Jackson. He adds that with a '100 knot tailwind on the return journey and going downhill we covered the 270 miles from Woomera to Mallala in thirty-eight minutes, possibly breaking all existing speed records.'
13. Jackson.
14. Contribution from W. D. Brown in 1980.
15. Contribution from J. M. R. Frost in 1982.
16. Bonnell.
17. See footnote 6. Once the stars had been identified, one had a large number of spot reference positions from which the graticule grid which also appeared on the photograph could be accurately calibrated. The photography was done by opening the capping shutter repeatedly, for minutes at a time. As the earth rotated the star images trailed across the film in a series of

curved broken lines. The shutter had to open and close at times accurate to the second, and this was done by a time count from an operator at CH who was closely watching the face of the phonic motor clock, which had been time calibrated using pips broadcast continuously by the distant US shortwave station WWV.

18. From it one could get synchronised square wave, pulse and delayed pulse signals at frequencies between 1-1000 hertz including the special 4 hertz timing needed for Askania kinetheodolites and the 20 hertz service for Contraves kinetheodolites (two of which were installed on Range A for a few months only in 1956 before being moved to Range E). All these signals were derived from a temperature controlled 100 kilohertz quartz crystal oscillator accurate to a few parts per million. There was also a rack of mixer amplifiers which allowed one to mix signals and gate them on and off at preset times.
19. Reminiscence of P. V. Moran at an interview in 1983.
20. Contribution from G. E. Hicks in 1979. Hicks gave the speed of the plane as 400 knots, but this is about the double the likely figure.
21. Reminiscence of Pat Finch (née Davies) at the Computers' Reunion of 29 August 1983.
22. The account of this incident blends the recollections of V. J, Bosher and the version in M. Garbett and B. Goulding, *Lincoln at War 1944-1966*, Ian Allan, London, 1979.
23. The third of the modified high altitude Lincolns arrived at Mallala from Britain in January 1950.
24. Of the three 'ballistic indices', one was based on trail (how far the actual bomb trailed behind the theoretical drag free trajectory in a vacuum); one on time of fall and one on range. The 'trail' figure was the most reliable and was used in setting bombsights. 'Terminal velocity' figures were often used instead of ballistic indices, although less so in Australia. Terminal velocity is theoretically the final velocity of the bomb in a 'standard atmosphere', when its tendency to accelerate under gravity is balanced by atmospheric drag.
25. Reminiscence of W. R. Watson at an interview in March 1985.
26. W. R. Watson, 'Problems in bomb ballistics—1955.' WRE Technical Memo WRE-TRDTM-1, November 1955. DRCS Library ref. SWM32132R.
27. It appears that Blue Danube trials had already been held some years earlier, and that this was simply a new series. Communication from S. J. Price, 1985.
28. The RAF took delivery of the Vickers Valiant in February 1955. It was followed by the Avro Vulcan in August 1956 and the Handley Page Victor in November 1956.
29. WRE Progress Report, July-December 1955, p23.
30. The word 'fuze' is normally spelt with a 'z' to distinguish it from 'fuse', the device designed to protect electrical circuits by melting on overload. The OED gives the two spellings as alternatives for both words, but this is not the practice in the industry.
31. W. A. S. Butement, 'Electronics applied to a number of problems: record of scientific work undertaken . . .' Unpublished DSc thesis, University of Adelaide, 1960. See also Ralph B. Baldwin, *The Deadly Fuze: the secret weapon of World War II*, Presidio Press, San Rafael, Calif., 1980.
32. Report dated 17 May 1949 from the Trials Officer. File SA5168 part 1. East has since commented (letter of 16 January 1986) that his scientific team was most concerned about accurate bombing, not only because of safety but because large errors meant loss of technical data. The team worked closely with the aircrew which always had the final say on whether to release or not.
33. The Chemical Defence Establishment Porton Down has commented that the mustard gas bombs were never deployed and that, 'offensive matters were abandoned by the UK in 1957 and all Chemical Warfare weapons eventually destroyed'. Information of 18 February 1986.
34. DGWRD Newsletter No 1, September 1947. The other three top priority projects were guided missiles: Seaslug, Red Heathen (which led to Thunderbird and Bloodhound) and Red Hawk (which emerged as Blue Sky).

11 Early missile trials: The Test Vehicles

BACKGROUND

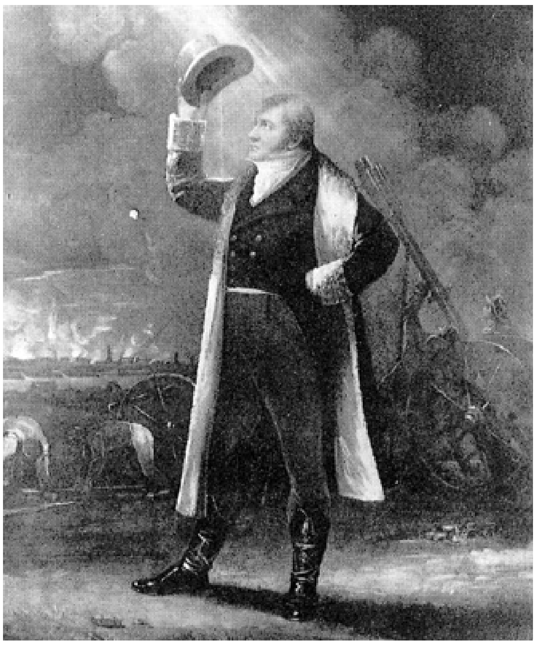
> Then the word was given to start up; and the rocket men, throwing in their diabolical engines with extraordinary precision, simultaneously with a well-directed volley from the infantry, the confusion created in the ranks of the enemy beggars all description. I saw and conversed with a French sergeant who was taken in this affair. He assured me, that he had been personally engaged in twenty battles, and that he had never known the sensation of fear till to-day. But a rocket, it appeared, had passed harmlessly through his knapsack, and such was the violence with which it flew, that he fell upon his face, not stunned, but stupefied—so frightful in his ears was the hissing sound which the missile sends forth in its progress. Nor is it the least appalling incident in a rocket's eccentricities, that you see it coming, yet know not how to avoid it. It skips and starts about from place to place, in so strange a manner, that the chances are, when you are running to the right or left, to get out of the way, that you run directly against it; and hence the absolute rout which a fire of ten or twelve rockets can create, provided they take effect. But it is a very uncertain weapon. It may, indeed, spread havoc among the enemy, but it may also turn back upon the people who use it, causing, like the elephant of other days, the defeat of those whom it was designed to protect. On the present occasion, however, it proved materially serviceable, as every man can testify who witnessed the result of the fire.[1]

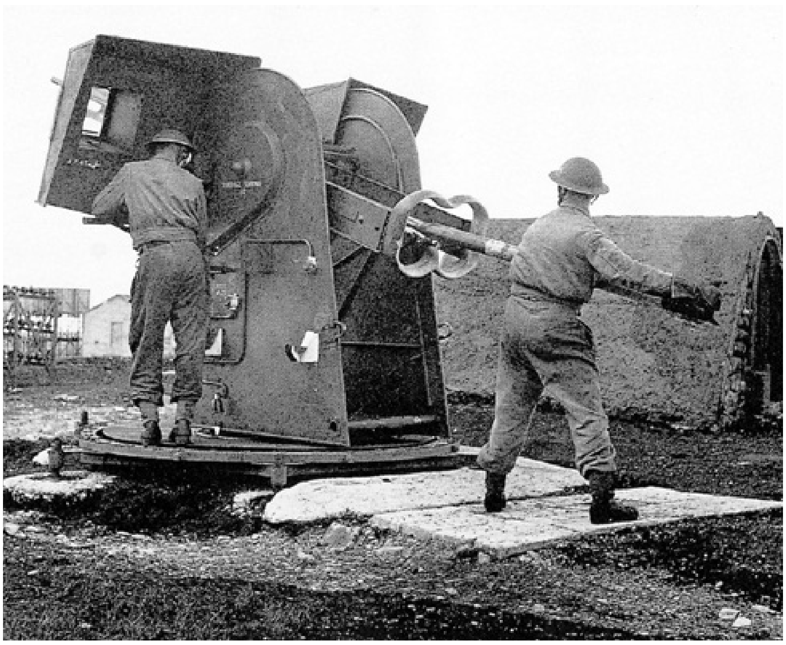
Thus did George Gleig, a subaltern in Wellington's army, describe the work of a rocket brigade during the Peninsular Wars. Perhaps it was the sheer unpredictability of Sir William Congreve's war rocket, so vividly described by Gleig, that caused its virtual neglect by British military engineers over the next century or more. Such rockets as were used even in World War II were hardly taken seriously by artillerymen. An officer of the School of Artillery at Larkhill, writing just after the war, described their flaws. They were, he said,

> extremely simple, and the danger lay in the electric circuits which fired the rockets. These were of a very primitive design, and often functioned when least intended.

Below left: Sir William Congreve (1772-1828) directing the firing of rockets that he invented into Copenhagen in 1807. From a picture by Clint after J. Lonsdale. (Hulton)

Below: Loading a British unguided anti-aircraft rocket into its launcher during World War II. (IWM)





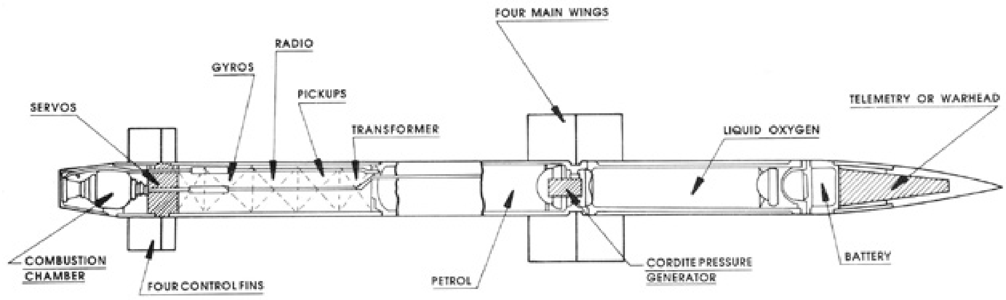
German anti-aircraft and other guided weapons on display at Farnborough in October 1945. (RAE)

> Added to that, owing to the shortage of manpower the weapons had often to be manned by the Home Guard, and you have a pretty good idea of their military popularity. Nor was their popularity with civilians at all greater. For the latter soon found out that the rocket tails, just like ordinary Guy Fawkes rocket sticks, came down just as they went up. In fact the civilians wondered at odd times which was worse—one German Bomb or 128 Rocket Tails. 128 because, in order to overcome the various inaccuracies inherent in the rocket, the weapons (usually twins) were sited in vast quantities—sixty-four. The effect from the ground—if not from the air—was terrific.[2]

As we have seen in Chapter 1, however, the experiences of the latter stages of the war had left British defence planners in no doubt that military rocketry had a potential that must be realised, and quickly. Allied air defences were inadequate already and would become more so. The anti-aircraft gun was obsolete and would be impotent against the new generation of high altitude bombers—a fact conclusively proved by gunnery trials conducted in Australia in 1952; trials which sounded the death knell of the UK Anti-aircraft Command. The Germans had not only perfected the two bombardment weapons, V1 and V2, but had also taken a formidable armoury of other guided missiles to the brink of, or actually into, production. The development of such ground-to-air missiles as Wasserfall, Rheintochter and Feuerlilie had proceeded far, and only the end of the war forestalled their coming into service. Actually used for part of the war was the Henschel HS293 radio-controlled, rocket-powered gliding bomb, the antecedent of the British Blue Steel and other stand-off weapons, launched against allied shipping after August 1943. One version under test even had a television 'eye'. Most of this German expertise passed directly to the Eastern bloc soon after the end of the war.

British wartime research into guided weaponry did not advance with anything like the speed of the German effort, but by 1945 they did have four guided missile or rocket test vehicle projects in train. The very first guided rocket missile to be developed was the ground-to-air Brakemine. The Brakemine project started early in 1943 and by the late summer of 1944 the first dummy round, propelled by a cluster of six standard 3 inch UP (unrotated projectile) solid rockets was launched over the North Sea. The engineers who worked on Brakemine and its successors were faced with some formidable problems. Their knowledge of the best body shapes and the aerodynamics of a missile flying through the sound barrier was far from adequate; nor were the guidance and control mechanisms required for Brakemine any less of a speculative venture. The best thing was, as usual, to work from the known to the unknown. Ground radars already existed which were capable of locking on to an aerial target and following it across the sky, so Brakemine would be a beam rider; that is, it would steer itself down the centre of a narrow conical radar beam locked on to the target aircraft. How such a system could be made to cope with several targets simultaneously during an air raid was problematic to say the least, but the first step was to get a simple missile working and so gain experience. The war ended before more than a few rounds showed any sign of riding a radar beam in a convincing manner, but the experience garnered from Brakemine was applied to a more enduring project, LOPGAP, described below.

In the latter stages of the war, in December 1944, the Munitions side of Britain's Ministry of Supply issued a requirement for a medium range guided missile. The requirement called for a rocket able to fly at 1120 kilometres per hour to a ceiling height of 40 000 feet



Main components (less the booster section) of the Liquid Oxygen-Petrol Guided Antiaircraft Projectile (LOPGAP), developed late in World War II as an early British guided weapon. It was renamed Rocket Test Vehicle No 1 (RTV1) in 1947.

and a slant range of 17 kilometres. If possible its weight was to be kept below 1½ tonnes. The code-name given to this requirement was LOPGAP: Liquid Oxygen and Petrol Guided Anti-Aircraft Projectile. Asiatic Petroleum, one of the companies working on rocket boosters to assist the take-off of heavily laden bombers, had produced a rocket motor which burnt petrol in liquid oxygen and delivered 900 kilograms of thrust for 25 seconds. LOPGAP would use a smaller version of this engine, at least at first.

In its original design by the Armament Design Department of the Woolwich Arsenal, LOPGAP consisted of a central body 4.3 metres long surrounded by a cluster of seven 127 millimetre solid motors. At the start the propellant in these motors was cordite but later they used an improved plastic propellant in an alloy case, the combination being known as LAP or LAPstar. The booster motors burnt for 3.6 seconds, taking LOPGAP up to a velocity of 460 metres a second. After the boosters had burnt out and separated, the integral liquid engine burnt for another 20 seconds. During this period 61 kilograms of LOX and petrol were forced into the combustion chamber by pistons, the pistons being driven down the two cylindrical tanks by gas pressure from a generator burning ammonium nitrate.[3]

By the time the war ended thirty-five LOPGAP dummies had been fired. The dummies were steel shells with fixed wing and control surfaces, propelled first by the cluster of boosts and then, after these jettisoned, by a small solid motor simulating the behaviour of the liquid sustainer. Although the original requirement was withdrawn, the R&D work continued with a high priority. Early in 1947 the responsibility for it was transferred to RAE under a new code-name, adopted in 1948, of RTV1 (Rocket Test Vehicle No. 1). As the new name suggested, RTV1 was a pure research tool, a flying test bed used to gather fundamental data over a period of several years. Though some of its features and design principles were incorporated in later British guided weapons and even in the big rocket projects, RTV1 itself was never intended to be a service weapon.

RTV1 IN AUSTRALIA: PREPARING THE WAY

By the time LOPGAP became RTV1 it had already been slated for trials at Woomera. At its second meeting in London on 9 October 1947 CUKAC had decided that the trials of the complete vehicle under guidance could not be handled by the small missile range running out over the sea at Aberporth, Cardiganshire. Therefore not only did a good deal of trials equipment need to be collected together, transported and installed at Woomera, but some of the Australian trainees had to acquaint themselves with the equipment and the vehicle itself. During 1948, two of the Evetts eleven, John Caddy and Chuck Bayly, worked on the provision of the Range facilities. In Britain the new and rapidly expanding Guided Weapons Department of RAE hosted a small contingent of young LRWE trainees. The first to be assigned to RTV1 work was Des Barnsley, and like many of the others he went on to spend a large part of his career on joint project work.

The working practice at Farnborough was to break down a new R&D task into a number of self-contained sections each able, as far as possible, to be tested individually. In this case the plan called for several versions of RTV1 to be built and flown. Each version was identified by a different letter or number suffix, and each was concerned with a different aspect of the control, guidance, propulsion and aerodynamics of the complete rocket.[4] It was both practicable and economical to prepare and test some of these versions at Aberporth. Both dummy and cold rounds, which were not fitted with sustainer motors, could be fired there safely to gather data on the flight programmer, the roll and lateral control, and the radio command link. Even some hot rounds, those with the sustainer active, could be fired with the tanks partly filled; and indeed the historic first two RTV1 hot rounds were fired there on 3 July 1948. For the time being all the action was at Aberporth and elsewhere as Britons and Australians alike wrestled with the multifarious problems of the brand new technology of guided weaponry. Only the later firings which fully extended the performance of RTV1 would need the Woomera vastness.[5]

Meanwhile Woomera was building. Chuck Bayly, who had gone back home in January 1948 to discover what facilities were needed, had the job of importing the German Askania kinetheodolites and the high speed Vinten cameras and getting them installed on the Range.[6] There was much else to do. Radar and doppler tracking had to be organised. Scales and other measuring and alignment equipment to set up the rockets and determine the centre of gravity had to be acquired. Operators and technicians had to be trained in every aspect of the work. There were lines of supply for the propellants to be set up with local manufacturers. Enough liquid oxygen for the modest demands of RTV1 was available from the firm of Commonwealth Industrial Gases, which prepared it for the BHP steel plant at Whyalla. Other fuels and oxidants were very unpleasant and dangerous chemicals, and special arrangements had to be made for their handling and storage. Supplies of the boost motors had to be shipped, at a time when transport companies were reluctant to handle any sort of potential explosive. Cordite charges to suit the booster rockets could be made locally at the Maribyrnong munitions factory in Victoria, but the special plastic propellants for LAP and LAPstar, used later, demanded the importation of special chemicals, presses and machinery to fabricate the light alloy casings. All the arrangements had to be made using communications which were very primitive by later standards: sea mail was the usual routing for correspondence, and air mail and telexes were most exceptional. The physical circumstances were very remote from the experience of visiting Britons like Bayly. It was worlds away from the cosy Welsh sea coast where avid punters could stroll down to Aberporth village and phone their bets through at lunch time. Small wonder that Bayly complained that the logistic problems facing him in Australia were beyond the imagination of some of those in London and Farnborough.

Chuck Bayly. Morien Morgan, Boswell and Norman Coles (*left to right*) during a visit to Woomera.

The Aberporth missile range on the west coast of Wales, looking south on a clear day in 1984. Firings are seaward to the north and west. (RAE)

As 1948 gave way to 1949 planning and preparation turned to tentative beginnings at the Range. Norman Coles, who had been a member of the 1946 Evetts mission but was now chief of Trials Division in the Guided Weapons Department of RAE, explained that there was little chance of any development trials for RTV1 at Woomera before early 1950. Meanwhile, he proposed a program of firings of (among others) small solid and liquid propellant rockets to familiarise the staff with the devices, their liquid fuels and the instrumentation. He also wanted to test the efficiency of the British supply side of the operation.[7] To oversee and assist this program, an RTV1 Australia Working Party was set up in London. At its third meeting on 24 March 1949, which was attended by Boswell and Caddy from Australia, a trials program was agreed for the period July 1949 and October 1950. Based on the Coles proposals, it consisted first of a series of firings of captured German Taifuns, small 100 millimetre liquid propellant anti-aircraft rockets. Six hundred of these had been made in the last year of the war and most of them had fallen into Allied hands. Britain would supply 150 Taifuns, and another fifty copies might be manufactured in Australia. Later would come larger dummy rounds of Seaslug (the first service guided weapon developed, and also a beam rider) and RTV1. These would give experience in handling larger rockets fitted with boosters and give practice with the kinetheodolites and the doppler velocity measuring gear. Later still, towards the end of 1950, might come first static and then Range firings of hot rounds.

FIRST LRWE ROCKET TRIALS: PORT WAKEFIELD

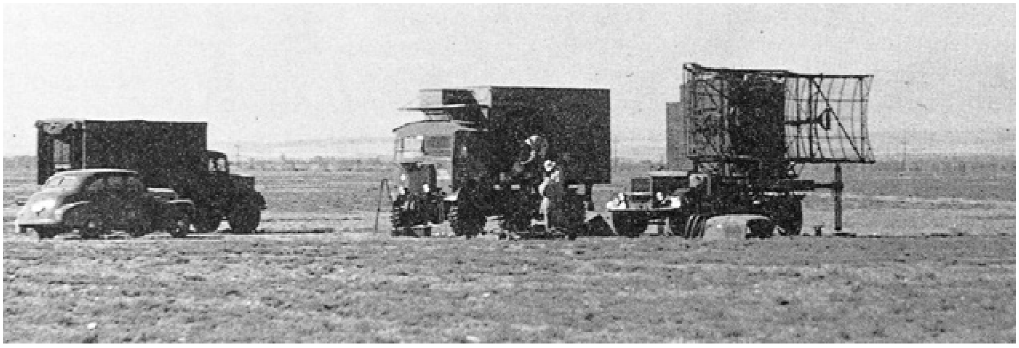
By the time this very first trials program had been formulated LRWE had already fired some rockets, though not at the Range. Bill Boswell's recently formed Electronics Group had been busy in late 1948 preparing the electronic instruments to be used in the forthcoming trials, and Boswell had decided to mount a preliminary exercise to check them out and practise operating them. Woomera could not yet handle such an exercise, but there was an existing Army proof range at Port Wakefield, 65 kilometres north of Adelaide. Apparently Boswell made unofficial arrangements with the Army to provide their range for these trials and to fire shells and rockets. For some reason he did not seek official approval for the trials and suppressed mention of them. They went down on the record afterwards as trials 'carried out at Port Wakefield to prove doubtful cordite rocket motors (and for other purposes.)'[8] Perhaps the Army really was interested in checking its suspect stocks of wartime 3 inch UP rockets. Or perhaps this was just an excuse.

Boswell gave the job of organising the instrumentation to Ross Treharne, then a senior officer in Electronics Group. His young team of electronics experts got it all ready and installed it in vans which they drove up to Port Wakefield in February 1949. Here the various vans and trucks were sited 'down-range' of a specially provided rocket launcher, which was

A 3 inch UP rocket in the special concrete launcher at the Port Wakefield proof range, during LRWE's first rocket trials.

nothing more than a heavy concrete block with a groove cut in it to set the trajectory. Then after a few preliminary shell firings the Army shot off their 3 inch UP rockets. The RAAF also co-operated by dropping 110 kilogram inert bombs on the shores of St Vincent's Gulf.

The main instrument to be tested was what the team jokingly called their 'black market' doppler, which David Robertson and others had cobbled together from a war surplus Admiralty transmitter, a couple of receivers, and a pair of four-element Yagi antennas fashioned at Salisbury. This doppler succeeded in picking up echoes from the shells and rockets after firing. During each rocket's brief flight Doug Mudgway and Frank Brogan tried to detect it with a one-gigahertz AMES XI radar. This had formerly been used in Singapore and setting it up again was a complicated job made worse by its arrival without any drawings, manuals and even a few of the essential parts. Though Mudgway and Brogan could see something on their screen, they were unable to capture anything on film. In disgust they threw the blank film outside on to the ground—whence it was carefully retrieved by the Security Officer and formally destroyed. It was all very primitive by later Range standards, but in rude outline not so very different from even the largest trials operations at Woomera over the following years.[9]



Some of the LRWE instrumentation vans at Port Wakefield. At the right is the AMES XI radar.

FIRST ROCKET TRIALS AT WOOMERA: RANGE F

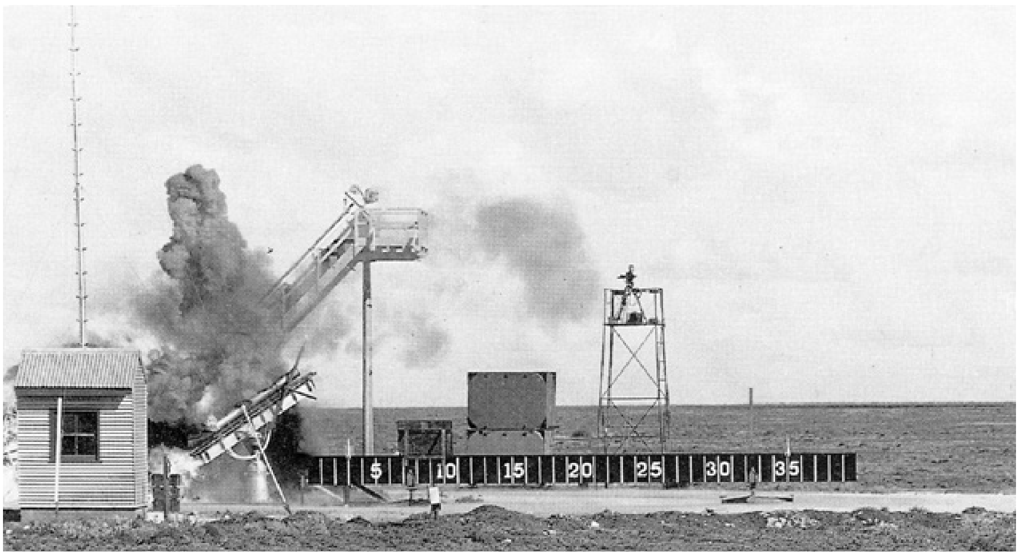
After the Port Wakefield preliminaries, the venue for these early missile trials soon shifted to Woomera where it remained. But not yet to the carefully designed main range, not for some years. In 1949 the future Range E was far from finished and the rangehead area was full of workers, particularly the 'Balt' labourers who so troubled Security. To avoid having to evacuate the site every time a secret round was fired, the Board agreed that the early missile trials should take place elsewhere. Accordingly an interim missile range, later known as Range F, was established with its launching point 8 kilometres west of the Range E launcher area. Its line of fire ran some 20 kilometres SSW to an impact area 15 to 20 kilometres away on Lake Hart, and it was on this interim range that the first rocket ever to be fired at Woomera was sent aloft on 22 March 1949. It was one of a number of practice rounds, using 3 inch UP rockets. These were the same pipe-like objects which had rattled onto British rooftops during the war, and the same as those fired the previous month at Port Wakefield. Indeed, uncomplicated solid propellant rockets such as these were to continue being fired on Range F and the later missile ranges until quite late in the joint project, and always for the same purpose of training and instrumentation check-out. For the pioneering attempt the launching point was shifted forward to Goalen Bluff overlooking Lake Hart, so that the rockets could impact on its soft salt-encrusted surface. Among the many interested witnesses were the Wirraminna station people, who watched from the back of a truck parked carefully at the base of the Bluff out of sight of the Safety Officer.

In late August and early September came the first essay at a missile trial that was not just a training exercise. It was part of the first item in the trials program agreed by the RTV1 Australia Working Party the previous March. Army personnel stationed at Woomera cautiously filled nine of the captured German Taifun rockets, now known as '4 inch LPAA', with WAF 1 fuel (aniline and furfuryl alcohol) and nitric acid oxidant. Then, at a firing elevation of 45°, each rocket in turn came spinning out of the launch projector, arching over the cliffs on the north shore of Lake Hart and into the lake bed. These trials were only

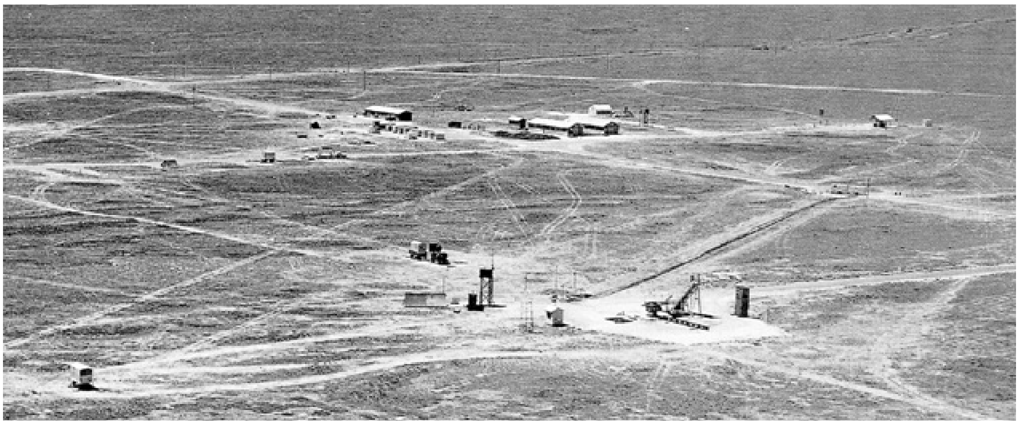
Spotting impact of the first rockets fired at Woomera in early 1949.

partially successful in meeting their objectives, which were to obtain ballistic data about their performance as well as to train Range personnel in the handling of dangerous fuels and the art of tracking fast moving rockets with kinetheodolites and Vinten cameras. The visiting UK experts returned home satisfied that Woomera could handle and fire small liquid propellant rockets, but no useful ballistic data were forthcoming owing to various instrumentation problems. Mudgway discovered a problem of a different kind when he tried to track the LPAAs with the AMES XI radar placed as close to the firing point as possible. The air-conditioning unit filled the van with filthy acrid brown fumes unless it was turned off just before firing. Other anxious moments followed when, in a couple of cases, rocket motors split their seams and the opened-out bodies, blown by the wind, appeared as echoes of increasing size heading for the van.

By December 1949 the instrumentation problems had been attended to and over thirty LPAA rockets had been successfully fired, most of them in one day. This time most of the firings gave acceptable ballistic data. By now the interim range was equipped with two AA No. 3 Mk 7 radars; a three station version of the 'black market' doppler; three Askania kinetheodolite vans and two high speed cine camera vans—all connected by army field telephone wire strung untidily over the gibber strewn plateau. The recovery of rocket remains from Lake Hart proved difficult as even jeeps became bogged in the unstable surface crust. To deal with this a special vehicle, the mud jeep, was created. This was a jeep fitted with enormous wheels and balloon tyres taken from a Beaufort Torpedo Bomber, which spread the weight and allowed it to roam safely across the treacherous saltpan.



A fire on the launcher aborts an attempted 4-inch LPAA firing during a later series of trials on Range G.



Part of the short missile range (Range G) used for early trials of RTV1 and other missiles. It was conveniently near the Technical Area and Woomera Village.

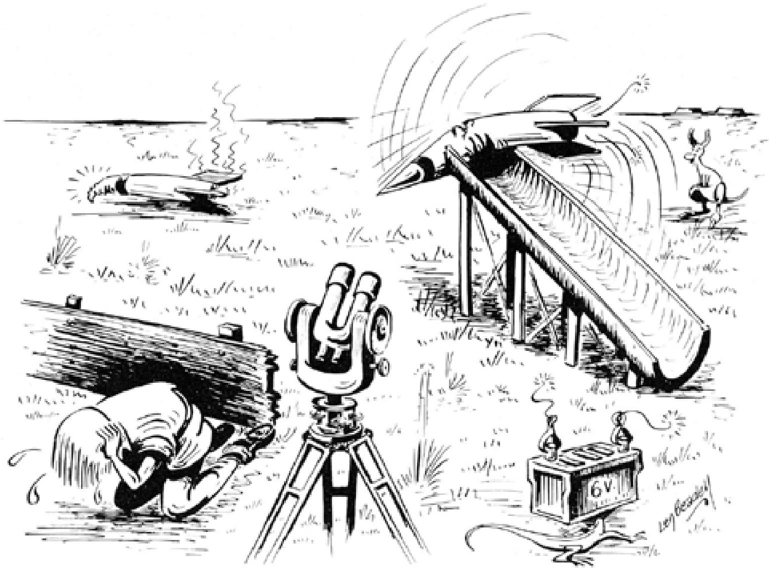
THE MOVE TO RANGE G

Although the Board had approved the creation of the interim Range F expecting that it would do for missile trials until the main range was ready, it soon became obvious that it was far from ideal. The launching site was a long slow journey away from Woomera on rough tracks, and the distant observation posts on the other side of Lake Hart were even more inaccessible. Even with the mud jeeps, recovery was difficult. The haphazardly run field cables gave constant trouble. Range F had been set up quickly in a temporary fashion, and something far better would certainly be needed for the forthcoming RTV1 trials. Rather than spend money improving this inconvenient range, a search was made for a closer and more accessible site and one was soon found. The Board approved a new 'short missile range' (Range G) to be placed only 5 kilometres from the Technical Area. Its launching point was just off an existing road to the bomb ballistics range, not far from the turnoff on the Koolymilka road. The direction of fire was towards and almost parallel with that of the main range.

Range G was soon established and it became Woomera's main centre for missile trials until they were transferred to Range E in 1953. It was on Range G, in the presence of two British technical experts, that Australia's first RTV1 firings were held on 1 December 1949. They were demonstration firings, as instrumentation was not yet installed. First a dummy RTV1x was fired, and then a powered RTV1a. The day was hot and as the glacial LOX filled the tank much of it turned instantly to gas, venting from the escape valve with a fierce hiss. Denis Arnold, who had been enticed from design work on the first all-Australian Holden car a year earlier to help Bayly, remembers the last tiresome preparations:

> The subsidence of the exhaust plume eventually indicated a full tank and all was ready for a final electrical check of the firing and ignition circuits and removal of the safety pin before launch. Inevitably there were last minute problems either with Range instrumentation or faulty readings on the missile circuits which caused the firing to be aborted, and the whole pre-firing drill had to be repeated several times throughout a long hot day. It was with relieved feelings all round that the missile was finally seen soaring into the clear blue sky with an angry roar that seemed to voice its own built-up impatience and frustration.[10]

Having taken a rough fix on the point of impact some kilometres away, the recovery party sallied forth to find the crumpled remains. At once the benefits of a land range were demonstrated. The liquid sustainer motor of the RTV1a had failed to ignite, and the reason was apparent. The firing pulse was supposed to ignite a fuze which was to explode some black powder in a twist of paper, and this was in turn to ignite a solid fuel charge which was to light the methanol/LOX mixture. The paper was too thick and the fuze had failed to burn through it! Rather more obvious and spectacular misfires occurred some time later when two of the early Seaslug launcher dummies were fired. Many service personnel were involved in actually preparing and firing these early rounds and one of them, hard-working Lieutenant Commander 'Bunny' Hodge, was reckoned by some to be more than a little accident-prone. Hodge watched in horror one day as a round prepared by his team flopped off the launcher to the ground when only one booster lit. Nothing daunted, the team loaded a second on to the ramp and went through the familiar firing sequence. This time two of the four boosters fired, with just enough thrust to inch the heavy missile up the ramp, whence it too toppled to the ground and swivelled to point at the Vinten camera operator who



'Toppled to the ground'

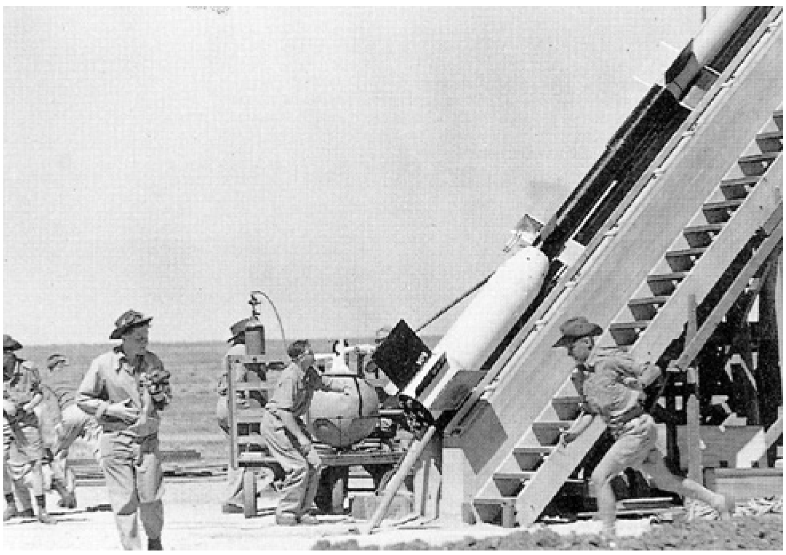
promptly dropped behind a three-ply screen for protection. Hodge's team had powered the firing circuits as usual with a car battery, but this time someone had inadvertently taken one from a vehicle with six volt electrics. RTV1 trials continued as the mainstay of Range G for the next three years.

There were also training and instrumentation trials in accordance with the Coles program, plus a second phase of Taifun LPAA trials. But Range G was also used for many other missile trials not contemplated in the 1949 programs, and they emanated from Australia rather than Britain. A new High Speed Aerodynamics Laboratory (HSAL) was set up at Salisbury in 1951 but not as part of LRWE—initially it was an outpost of Melbourne's Aeronautical Research Laboratories (ARL). ARL and then its offshoot, HSAL, seized the opportunity presented by the new Range G and the plentiful supply of small solid rockets to carry out aerodynamic experiments. The first such was in April 1950. A 3 inch UP rocket fitted with wings of a particular shape was launched and its trajectory measured. The aerodynamic drag on that wing shape could be calculated from the rate at which it slowed down after the rocket burnt out. Many such drag rounds were fired bearing wings of different shapes. There were similar drag experiments on various bomb shapes, as described in Chapter 10, and other rocket firings to investigate aerodynamic flutter. All of these used simple unguided rockets, but HSAL also did some early trials at Range G of the wire guided anti-tank weapon Project E, which is discussed later.

Range G closed as a short missile range soon after the RTV1 and HSAL trials relinquished it for Range E in 1953. Some five years later the rangehead area was used for a while as a satellite tracking station at about the time when the first Sputnik was launched.

Below: A hurried evacuation of the RTV1 launching area

Below left: One of the 1949 RTV1 launchings.



ORGANISING FOR THE EARLY MISSILE TRIALS

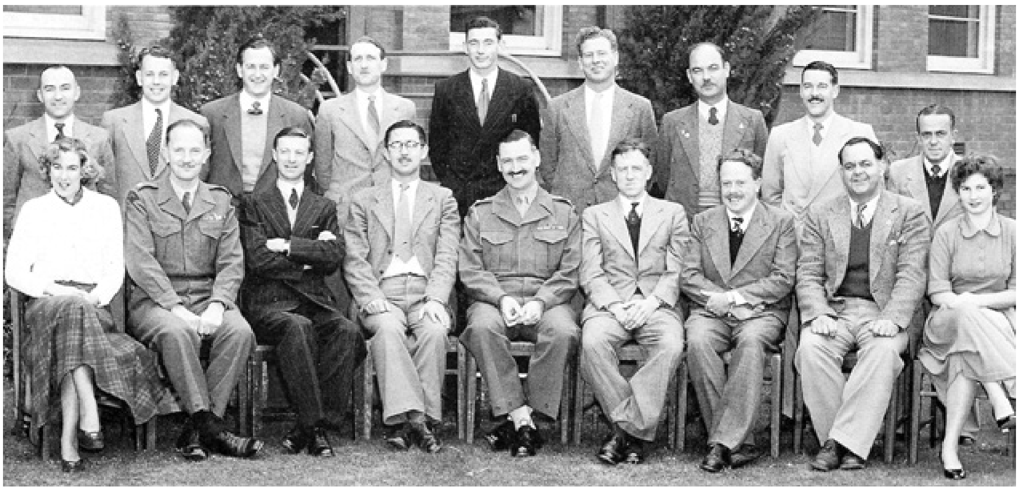
In the previous chapter we saw how in the first years of the project the bomb ballistics trials were organised separately from the missile trials. The division was so sharp that of the Salisbury part of LRWE only the administration, construction planning and engineering straddled the two. This split between the 'bomb' and the 'missile' sides lasted until the reorganisation of 1955 which produced WRE. Until 1953 Bomb Ballistics Group was alone responsible for planning bomb trials, instrumenting them, reducing the data and, with the help of Range and RAAF staff, actually conducting the trials at Woomera. The case was different for the early missile trials. No single group was in charge of them; many different groups had fingers in the pie. Electronics and optical groups provided the instrumentation and operated it too, until the Range staff were able to take it over; and Mathematical Services Group read the trials records and calculated the trajectories.

The trials roles of the various groups at Salisbury and of the 'Officer in Scientific Charge' were first defined in a circular issued in September 1948, when LRWE was formed by merging the earlier Base, Air and Experimental establishments. The circular covered the planning as well as the actual conduct of trials, but the proper organisation of missile trials really began with the formation in October 1948 of a Trials Co-ordination Group, with Caddy in charge. It lacked staff to do detailed planning for itself, so it worked through a Missile Range Working Committee with Caddy as chairman, drawing on the expertise of the many groups concerned.

By early 1950 RTV1 trials and others had started on Range G and many more were in prospect. A better way of planning trials had to be found; one which did not tie up key members of staff in meetings for hours on end. In June 1950 a small Trials Section (soon to be Trials Group) was created by transferring three officers from other groups; Jeff Heinrich from Electronics, Phil Norman from Trials Co-ordination, and Bruce Pitt from Optical. In November Lt Col John Howard, who had been Staff Officer to the 1946 Evetts mission and had later been attached to the Ministry of Supply in London, returned to become Principal Officer of Trials Group. The old Trials Co-ordination Group disappeared and soon after Caddy returned to Britain.

Howard's first task was to simplify and formalise the trials procedures. Drawing on his army background and the wartime experience of his staff of three, Howard developed a Trials Instruction which, in the same minute detail as an army operations plan, specified exactly what was to be done at each trial, how it was to be done, and who was to do it. Trials Instructions grew more comprehensive with the years but they persisted right through and indeed past the end of the joint project. Trials Group itself expanded quickly. A section was added to plan the forthcoming Jindivik development trials. Later another section, Facilities Planning, was created under Horrie Higgs to assess future trials projects and to decide what was required for them so that everything was ready in time. These requirements were listed in the Trials Specification—a much broader document than a Trials Instruction in that it dealt with a whole series of trials, not just one.

Trials Group was a hive of activity in those early years. Its task was essentially co-ordination and paperwork, which admirably suited its leading figures like John Howard



Trials Group, set up in 1950 to plan missile trials. Its leader Lt Col John Howard (*front row centre*) had been the Australian Staff Officer for the 1946 Evetts mission. Navy-trained Phil Norman (front row second from right) took on the preparation and control of trials.

with his organisational skills and the meticulous Jeff Heinrich. Another active and strong personality was Phil Norman, who had the onerous task of trials preparation and control. Norman ran his trials with great dynamism, throwing himself into the role of 'controller' and barking instructions down an intercom as though he were still conning a ship in the wartime Navy.

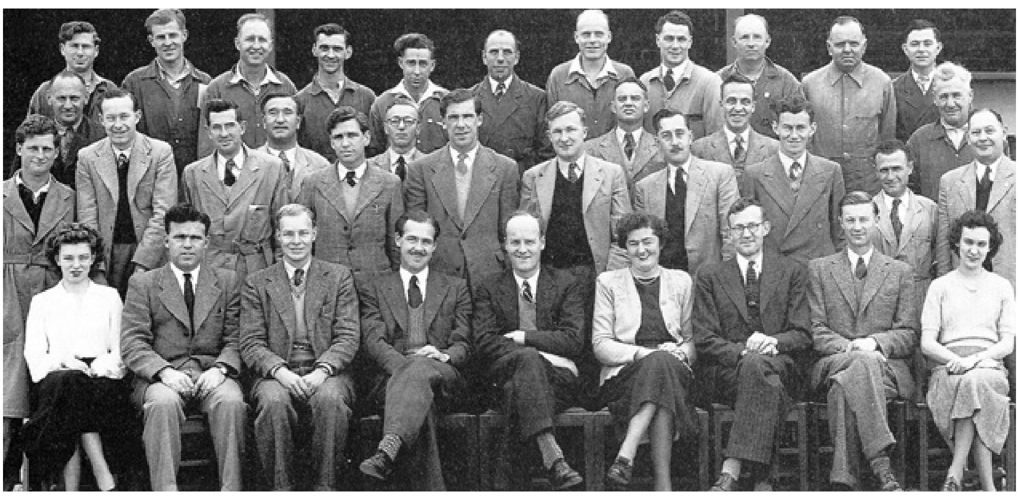
At a reorganisation of LRWE in June 1953 Trials Group was renamed Missile Projects (MP) Group, now with Heinrich in charge as Howard had been moved to other duties. It temporarily lost the section devoted to air trials including Jindivik, for this was hived off into an Air Projects Group; but at the absorption of LRWE in a larger WRE in 1955 the Missile and Air sides were at last integrated and remained so until the end of the project. Nevertheless, despite its expanded functions MP Group retained its name until much later (1968).

In organising trials there was from the beginning a clear distinction between the parties that used the Range and those which controlled it; a distinction later formalised under the labels 'range user' and 'range authority'. The user supplied and prepared the test vehicles or weapons to be tested on the Range; he specified the scientific requirements of each trial and supplied the Officer in Scientific Charge (OISC). The range authority planned, instrumented and conducted the trial, looked after safety and reduced the data, except that the user was present at the trial and he operated the equipment associated with the particular missile under test. In the case of RTV1 and other test vehicles it was RAE who was initially regarded as the user, but when LRWE was formed in September 1948 a Test Vehicles (TV) Group was provided to support RAE, although it existed at first in name only and had no staff. In March 1949 two men were transferred into it: Denis Arnold and David Collingwood, a flamboyant New Zealander and Cambridge graduate. The first job given to TV Group was to prepare fuelling and test equipment and Arnold went off to Britain to explore the mysteries of LOX/methanol engines, which were regarded as extremely sophisticated engineering at the time. Collingwood stayed as temporary leader of the Group until December 1949, when Bayly returned from a long visit home and took charge. With his personality and experience with liquid motors at Westcott, he was the obvious choice.

Over the years TV Group grew large and changed its name and nature more than once, but at the time of the early missile trials its main interest was RTV1 and other test vehicles. It was of course not the only group concerned with RTV1, but the history of that project in Australia is intimately bound up with TV Group and its successors, and this thread of the story is the one traced below.

TEST VEHICLES GROUP AND RTV1

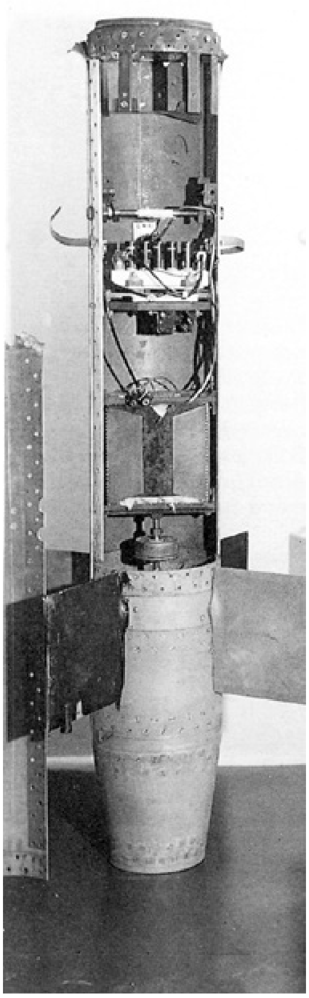
In 1950 TV Group's main task was to prepare RTV1 rounds and take the lead in their trials at Woomera. With Range G open for business the preparation rate increased as more staff were recruited. In March TV Group shifted to a more permanent home, Building 77 in the Laboratories Area[11], where RTV1 rounds passed on a kind of production line through a series of interconnecting rooms on the western side of the building to undergo assembly and various tests, including centre of gravity and moment of inertia measurements. Then they



TV Group in 1951, after Bayly (*front row centre*) took it over. On his right are David Collingwood and Denis Arnold, the original members.

were loaded on to a ramp at the southern end of the building for transport to Woomera. The eastern side of the building was reserved for offices and laboratories to test and assemble the components. The failure of the first hot RTV1a at Woomera had indicated the need for a static test facility for the sustainer engine at Salisbury, and one was set up just to the north of Store 2. The first test-firing was a roaring success as it rattled the windows in the Headquarters Area and startled the sparrows and other denizens of Store 2 in their normally quiet pursuits. Arnold, who was in charge of the first static rocket engine fired at Salisbury, remembers waiting several minutes with the Safety Officer, Russell Patterson, to make sure that all the fuel was burnt before wondering aloud if it was safe to approach the engine. 'You go ahead, old chap', replied Patterson. 'There's no point in both of us getting killed.'[12]

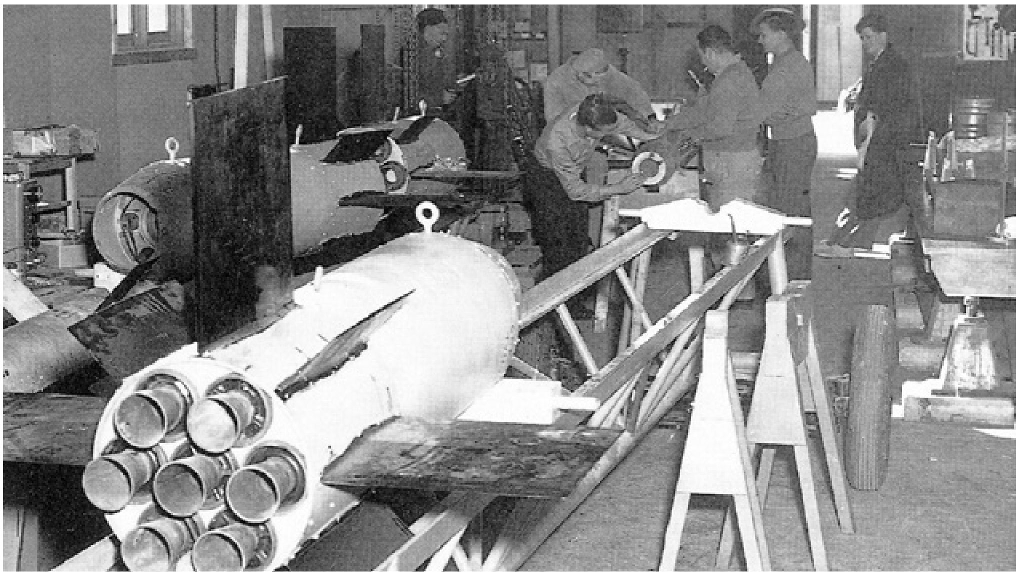
In June 1950, following a visit to Britain with Boswell, Bayly wrote a comprehensive paper which advocated that 'as a logical step, following the construction of the various ranges, some effort should be devoted to building up industrial potential for the eventual manufacture of test vehicles or complete guided weapons in Australia'.[13] He proposed that both dummy and motorised RTV1e rounds be manufactured by Australian industry, as well as the necessary boosts. This was not the first impact of RTV1 on local industry, as orders had already been placed on the Government Aircraft Factory in Melbourne for forty steel dummy rounds, and also on the Maribyrnong Explosives Factory for cordite and LAP boost motors. Bayly's ambition was to have the more sophisticated items such as guidance system components made in Australia as well, as a prelude to the manufacture of complete guided missiles. He also proposed that RTV1e should be further developed so that it could be used as a training round by the Australian services. The Board of Management praised Bayly for his paper and accepted the suggestion.[14] Later a developmental contract worth £300 000 to build forty of the advanced beam riding version of the missile went to Fairey Clyde Aviation, which by then had been established on the Salisbury site as an offshoot of the British parent. Fairey's used a number of subcontractors during production, the most prominent being the Royal Australian Naval Torpedo Establishment (RANTE) at Neutral Bay in Sydney Harbour, which manufactured and tested the hydraulic servo units, and the local subsidiary of EMI which built a number of guidance receivers and servo amplifiers. The Commonwealth Aircraft Corporation produced magnesium alloy castings, including one of magnesium zirconium alloy, which is extremely difficult to work. Not all parts of the vehicle could be produced in Australia, for some of them would have been unduly expensive. As it happened, one result of the later decision to cut back on RTV1e trials was that only a reduced number of the EMI copies of the LR3 Guidance Receiver and Mk 3 Servo Amplifier were ever built.[15]



Part of an RTV1 after recovery using a parachute technique. Note the thermionic vacuum tubes which survived.

TV Group was now beginning to gather in the repatriated trainees whose fresh knowledge equipped them for more involved investigations into rocketry. Although only five RTV1 rounds were prepared by the Group during 1950, two development tasks were begun. One was to investigate the effects of launcher length on round dispersion. The other, begun after Bayly and Boswell had visited Britain in March, turned into a major and prolonged task, that of recovery. The 'soft' recovery of missiles was a preoccupation of LRWE at the time. As a long land range Woomera had great potential advantages, but in the thinking of the day these would only be realised if some missiles could be prevented from smashing themselves on impact. To begin with, the parachute expert, Sid Jackson, who had helped conduct the first trials ever held at Woomera, was asked to develop suitable parachutes for a missile recovery system. A special Recovery Panel was set up and at its first meeting in November 1950 it proposed testing a number of arrangements for slowing down RTV1 rounds before releasing parachutes of various designs. Jackson asked RAE for suitable materials and they were stitched together by a clothing firm in Adelaide. The Panel heard at its third meeting in May 1951 that six of the eleven vehicles with nose break-up and two out of four tested with tail break-up were considered a success. It was obvious the Panel still had some work to do before the recovery system could be considered proven and indeed the task was to take several more years and to involve considerable effort.

Work done in 1950 was consolidated in the following year. Thirty-three RTV1s were fired, roughly four times as many as in the previous year including the last round to be fired for training purposes alone. By mid-year useful trials data was flowing back to Britain and helping the development there, and TV Group's staff had risen to forty. These included Treharne and Doug Mudgway, who had transferred from Boswell's Electronics Group, and new recruits, Don Bennier, Tom Cooke and John Dunne. Mudgway, Bennier and J. S. Howard



Preparing RTV1s for firing, in the missile assembly building at Range G.

were sent off to England soon after to familiarise themselves with the RTV1 guidance system and, after training at RAE, were given their own RTV1 to prepare and fire at Aberporth. It was a dud and it was only realised afterwards that by mistake they had been given reject and suspect units to assemble. It was a valuable if unintended lesson and emphasised the need to check and double-check every component.

Those at Salisbury had the additional job of passing information to Fairey to help with the production of the Australian RTV1e parts. With another fifty complete beam-riding rounds due to arrive from Britain as well, the guidance people were asking the obvious question: What was to be done with them all? The answer to this was delayed, and when it did come it had serious repercussions for TV Group. The development program in the UK had just reached the beam-riding stage and of the eight RTV1e rounds fired in 1951 only two were successful and another two partly so. RAE was under some pressure from Supply to show that it really could make a fully fledged beam-riding system work; and in trying to make its bird fly it was becoming aware of disconcerting radical weaknesses in the RTV1 design. Of course this was not surprising. The original designers had had to venture into supersonic realms beyond their experience and without the aid of a high speed wind tunnel.

In December 1951 Bayly's five-year contract ended and he returned to England. Bayly was missed. He had acquired his knowledge of rocketry through his service experience rather than academic study, but his outgoing and confident personality enabled him to work well with the Australian scientists and to use their special knowledge. He was replaced by Ross Treharne. Treharne's electronics background made him the appropriate choice now that RTV1 was through its training and propulsion stages and into the control and guidance phase. Under his leadership TV Group was to become much more an experimental organisation and one less strictly devoted to firing rockets for other people's experiments. When Treharne made his first tour of inspection he was heard to mutter that it sounded more like a 'bloody garage' than an experimental outfit. His remark was occasioned by a staccato burst of noise as someone fired a small cordite charge to pressurise the RTV1 hydraulic servos, and the relief valve let off a burst of noise like a machine gun. As well as the garage-like noises the whole layout had been influenced by George Lobb, Bayly's administrative officer who had worked for Ford before the war and had introduced the RTV1 'production line'.

Ross Treharne who took over TV Group from Bayly.

The following year, 1952, was another very active one for TV Group. They prepared and fired fifty-seven RTV1 rounds of increasing complexity, and their own staff expanded past the fifty mark. TV Group claimed that it could now prepare and fire between six and eight rounds a month, and was hoping for some tasks not so directly linked to RAE's immediate program. A review in mid-1952 showed that many, but not all, of these RAE trials were now nearing an end. Training trials had finished and much work had been done in such areas as comparative boost trials and lateral and roll aerodynamics. Most of the remaining RAE work was in the beamriding trials, which had hardly begun. However, a separate series of trials had already emerged and, although it had been suggested by RAE, it was TV Group and not RAE that was taking the leading role in tackling it. This series was known as the 'six-point program', consisting mainly of broad-based experiments into RTV1 performance. Thus there were trials to investigate guidance beam misalignment, the separation of tandem boosts and the effect of launcher length on dispersion. These three items had already been almost completed but the second three—vibration measurements, aerodynamics of the vehicle and tests of the recovery system—still posed many problems. RAE also proposed that LRWE should undertake a series of eight experiments on the beam riders, with thirty-two firings.

These were busy days for TV Group and morale was high. The sound of George Lobb's bugle summoning the staff to the cash desk on payday typified the spirit. Most of the staff were young and although they worked long hours and spent many uncomfortable days out at the Range, the overtime rates were good and they had the stimulation of working in a novel sphere of technology where they struggled forward from one set of fascinating problems to another.

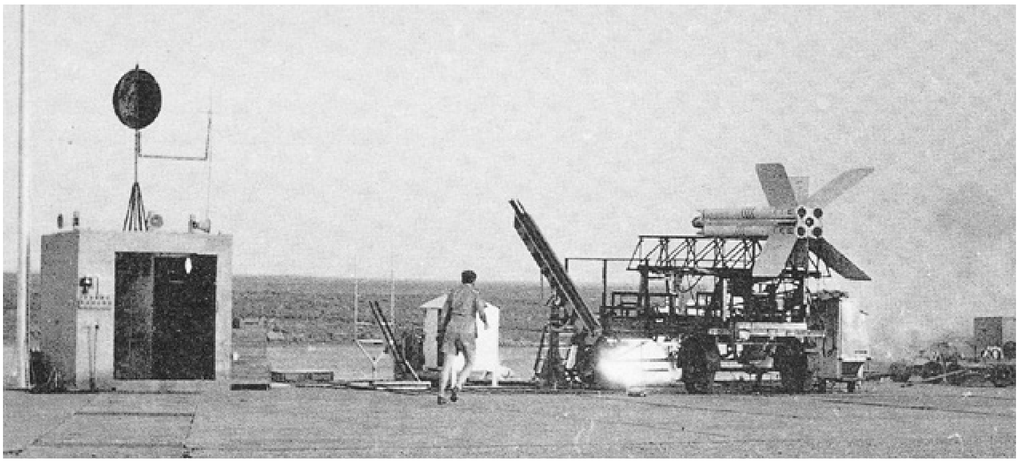
ENTER CTV5, AND TV GROUP REORGANISED

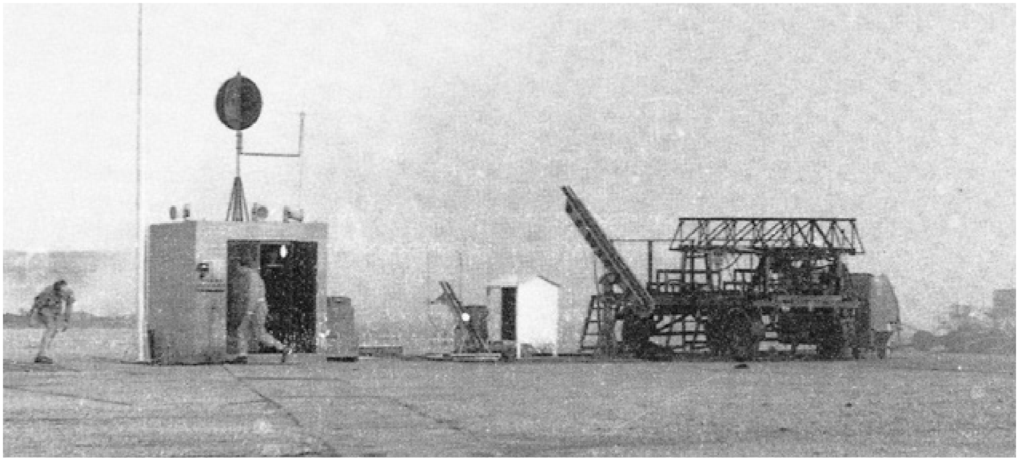
The last RTV1 was fired on Range G on 28 November 1952, and thenceforward all were fired at Range E, the first of them on 27 March 1953. The very next month, TV Group, which until then had been almost entirely concerned with RTV1, now also turned its attention to a new test vehicle known as CTV5 series I. This was the latest in a line of 'control test vehicles' that had been developed in Britain since about 1946 as part of the Lockspeiser policy of concentrating first on test vehicles and models rather than on missiles. Unlike RTV1, which had started life as the developmental weapon LOPGAP and became a test vehicle later, the CTV family of vehicles were planned from the start to investigate the aerodynamic control of missiles, particularly under tight manoeuvres. The various versions—CTV1, CTV2 and so on—differed in size and performance, but all were unguided and all used solid propellant motors rather than a liquid sustainer as did RTV1. The only versions fired at Woomera, apart from two CTV1 rounds used as sighters, were CTV5 series I and HI. The first series was a multi-stage rocket. The first stage boosted the test vehicle up to speed and then separated. Following a long coast up to heights of 10 to 15 kilometres, the second stage burnt and then fell away too, leaving the unpowered dart to coast freely at supersonic speeds, initially at over Mach 2.[16] During this flight small wing-like control surfaces were programmed to turn the dart sharply, so as to simulate a guided missile pursuing an evading quarry. The aerodynamic effects on the dart—drag, accelerations, roll and so on—were later computed from trials records.[17] Had these severe experiments been attempted at a lower altitude with RTV1, the drag of the denser atmosphere would probably have broken up the round.

R. A. Benson, blinded in the CTV5 accident, leaving RAE Farnborough with his seeing eye dog in 1959. (RAE)

A UK team led by T. L. (Tommy) Smith of RAE arrived on the Hastings service on 15 April 1953 with the first two CTV5 rounds, and both were fired on Range E only nine days later. TV Group helped prepare them for firing, and this event marked a crisis and a turning point for the Group. Previously the idea had been mooted that the CTV5 program should not be handled by TV Group but by another Supply facility, the High Speed Aerodynamics Laboratory (HSAL). From one point of view HSAL was the logical choice to conduct an investigation into high speed, high altitude flight. Naturally Treharne and others in TV Group did not share that view. They launched a spirited defence of their Group's ability to investigate and analyse trials results, and stressed their practical experience in launching rockets at Woomera. Treharne and Collingwood put their views forcibly both locally and on a visit to Britain, and they were successful in winning the work. To mark the change of direction TV Group was reorganised in June 1953 as Flight Research Division (FRD), with Treharne continuing as acting Superintendent. Its seventy-three staff formed four groups: Assessment, Control, Guidance and Test Vehicles. Henceforth the Division not only took a leading part in trials of test vehicles but had a clear brief to undertake all kinds of flight research into guided weapons techniques.

Two more CTV5 rockets were fired in September 1953, but the second firing was by accident. While it was being prepared on the launcher a flare in the dart ignited prematurely and propelled the whole rocket forward a few metres. This triggered an internal timing unit which fired the second stage motor: it blew off and landed some distance away with the dart still attached. Several of the launcher team were injured and one, R. A. Benson of RAE, was permanently blinded.[18] The Court of Inquiry later established that the cause of the accident was a short circuit when a plug was inserted, which ignited the flare. Serious though this





The CTV5 accident at Range E on 30 September 1953.

Left: Premature flare ignition has forced the second stage off the launcher. *Below*: The boosted first stage has ignited and landed 200 metres in front.

incident was, it is a tribute to the safety record at Woomera that it was one of only two missile accidents producing injuries during the whole life of the project. The other was a fatal accident involving a Blue Jay missile, mentioned in Chapter 17.

As well as its new CTV5 interest, FRD found itself taking more responsibility for RTV1 as British interest in that missile was clearly declining. By early 1953 most of the RTV1 team at RAE Farnborough had been transferred to other work, and a series of RTV1e beam-riding experiments was assigned to Australia. This was to present unforeseen difficulties for the new Division. Of the fourteen beam riders fired in 1953, only three were completely successful. Trials were then suspended altogether for six months to make a full examination of the problems. The pause saw a new Superintendent, T. F. C. Lawrence, take charge. An aerodynamicist from RAE, Lawrence was a tough personality well able to inspire—or if he could not inspire, to compel—his staff to attend minutely to detail. The problems FRD faced were manifold, involving every part of the RTV1 vehicle—propulsion, guidance, control and so forth—and collectively they were daunting enough to raise doubts whether RTV1e could ever be made to function properly. The propulsion system was apt to fail under sustained side forces. The propellent tanks flexed, jamming the internal pistons which drove out the liquid contents. This had not been detected at Aberporth, because there the tanks were always empty or only partly full. Also the ammonium nitrate which provided the gas pressure sometimes did not burn properly under fierce acceleration.

T. F. C. Lawrence

Then there was the guidance system. On the ground, the SCR 584 radar found the target and then locked a conical beam on to it and followed it. The guidance receiver in the RTV1 interpreted signals in this beam and by passing commands to the control system kept itself centred in the beam until it hit the target. It was a complex circuit employing many valves. More than a hundred of them were packed into the small interior, five times as many as in a television set of the period, and they often failed under the strong acceleration and vibration. Even if the receiver worked correctly it might not get the command data from the ground radar. The RTV1's antenna was not very efficient and as the missile twisted and turned it could blanket itself in a plume of ionised gas which blocked the signal. Another problem was a mechanically driven device known as a range potentiometer which was used in the guidance system. Some rounds failed when the potentiometer stopped turning because, it was later discovered, the little motor which drove it was too weak to turn it reliably. This had not come to light in England because RAE staff had carefully selected potentiometers that rotated easily.

These problems were collectively so radical that Mudgway of the Guidance Group was sent to the UK for discussions. He reported that RAE was preoccupied with their RTV1 'Q' trials[19] and appeared little interested in what Australia did. RAE did suggest several lines of investigation to the Australians including the development of a semi-active homing system using a radar receiver in the missile, but these were all long term projects. The truth was that the Australians were being left to do whatever they wanted with RTV1. The British regarded it as superseded. As they became more enmeshed in developing guided weapons to meet specific operational requirements, general test vehicles were falling from favour.

This largely confirmed the impression already received that FRD could no longer look elsewhere for guidance but would have to use its own initiative in future. After all, it was no longer TV Group but Flight Research Division, with a mandate to conduct research into the flight of guided weapons. At its disposal was an ample supply of rocket motors and an obsolete vehicle which could be monitored, altered, prodded and poked to find out more about supersonic flight. They were also busy with other research programs such as the CTV5 series I and had built up an experienced staff who, working in small teams, could examine various aspects of the vehicles.

ANOTHER NAME CHANGE, AND THE TEST VEHICLES FADE AWAY

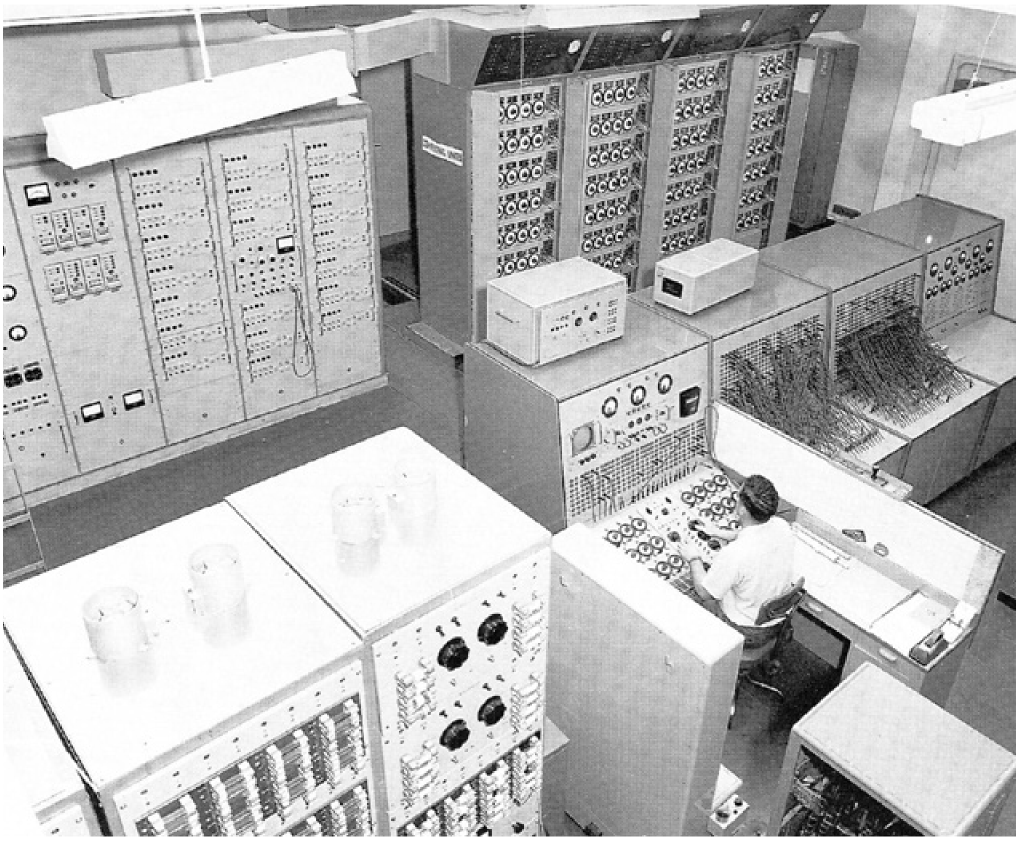
Having newly discovered its independence in flight research, the Division soon found itself facing another and severe change of direction, which would eventually lead it right away from preparing and firing test vehicles.

Since the earliest days of guided missiles in Britain, RAE Farnborough had been interested in predicting the behaviour of missiles by simulating them in the laboratory, at obvious savings in cost. Several simple RTV1 simulators had been built, using electrical or other analogs to represent key components of the missile system. During 1952 RAE had put much of its design effort into a large computer, TRIDAC (Tri-dimensional Analog Computer), which was to be used as an advanced missile simulator ('tri-dimensional' meant that it could handle flight simulations in all three spatial dimensions simultaneously). TRIDAC was to be built by Elliott Bros of London. Several of the Australian trainees were working on this project in England. As they returned, and as Bayly, Boswell and others learnt of the value of this new tool, they began to press for a copy of the RTV1 simulator to be sent to Salisbury. Boswell had earlier dismissed the need for laboratory simulation of missile behaviour, feeling it was only useful in the design stages, but ideas were changing and in October 1952 TV Group suggested that some of its staff should go to Britain and continue discussions that Boswell had had there on the subject.

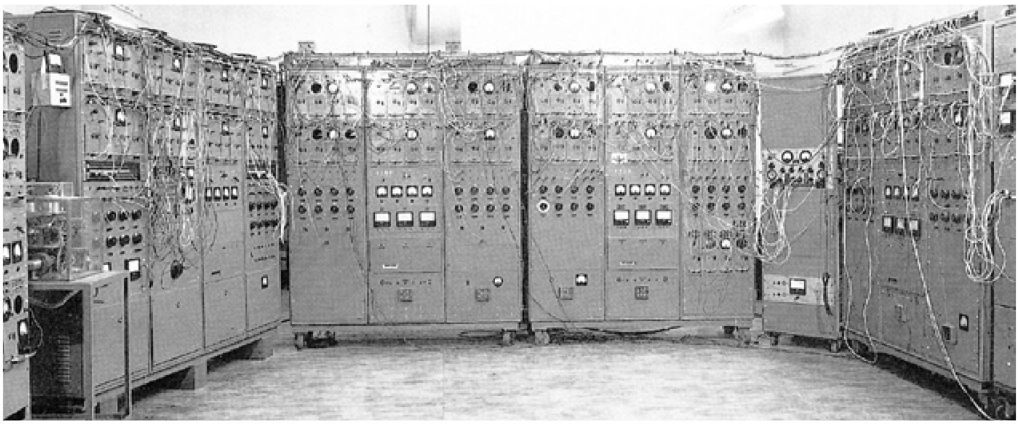
At first RAE resisted these solicitations on the grounds that Salisbury would not be doing much development work, but when the question of what to do with RTV1e came up again, both RAE and the Ministry of Supply took a more positive view. After visits to Melbourne and Salisbury from representatives of RAE's Guided Weapons Department in November 1952, Britain agreed to supply a smaller and simpler version of TRIDAC. This machine, also built by Elliott, was known as AGWAC, the Australian Guided Weapons Analog Computer.

While waiting for AGWAC, TV Group had designed and built its own simulator called ARTVS, the Australian Rocket Test Vehicle Simulator. This started off as a simple 'single plane' or two-dimensional device, but later it was expanded considerably. By early 1954 ARTVS had successfully simulated an RTV1 beam-riding flight in one two-dimensional plane. The three-dimensional AGWAC arrived and was installed and tested by the end of the year. Armed with these new tools, Flight Research Division turned its attention from routine firings at Woomera of the troublesome RTV1 beam-rider to laboratory studies of the simulated missile, although it was recognised from the start that actual firings would always be necessary to validate the model—that is, to check whether the simulation was realistic.

In recognition of this transition to system studies, as they were called, and closely



The AGWAC analog computer installed at Salisbury.



The LRWE designed ARTVS simulator.

following the general reorganisation at the beginning of 1955, FRD was renamed Systems Assessment Division (SAD).[20] Soon afterwards a recently formed Trials Assessment Group under W. R. Watson was transferred to SAD; its task was to evolve better ways of assessing weapon systems, designing trials and interpreting results. SAD was soon involved in discussions with two British visitors, Air Commodore Chacksfield who was Director of Guided Weapons Trials in MoS, and John Mercer who was head of Weapons Assessment Division at RAE. The visitors felt that SAD was now well placed to assist in the acceptance trials of the first UK air-to-air guided weapon, Blue Sky, which were soon to begin at Woomera. This work and similar assessment of the Blue Jay trials greatly occupied SAD teams in the years ahead but that is best left to the chapters dealing with the first and second generation weapons.

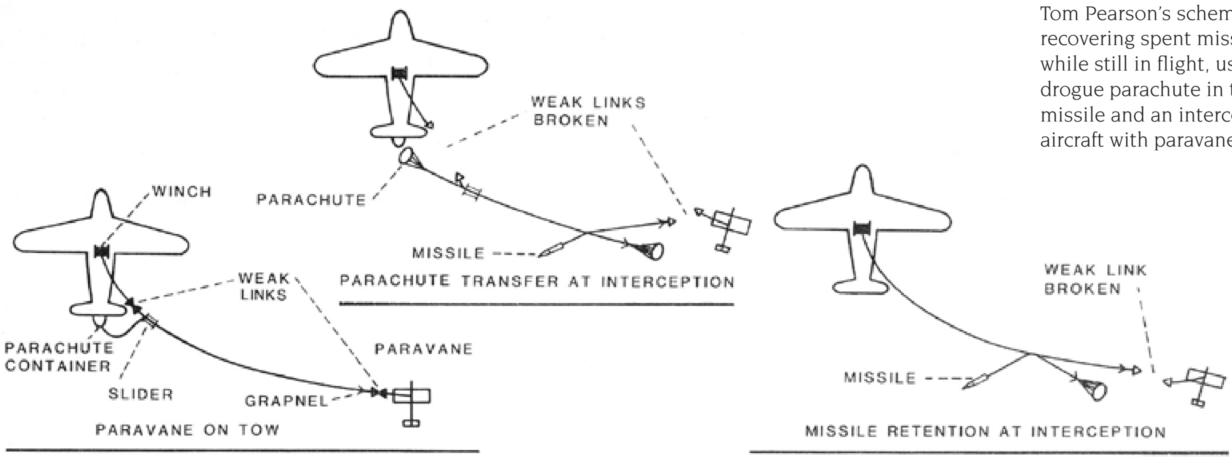
Despite the new direction SAD was still responsible for missile flight research, and its work on RTV1 and CTV5 trials continued for a while. During 1955 the Division prepared and flew twenty-eight rounds, fifteen of them RTVs and the rest Wing Body rounds (to test various combinations of wings and bodies) and CTV5 series I rounds. The RAE dropped RTV1 finally at the beginning of the year but SAD continued using it to investigate vibration, guidance, aerodynamic and propulsion effects. Most of these experiments were successful, but other trials where an RTV1 attempted to beam-ride a 'stepped' beam (one moving quickly from one direction to another) were a total failure—the guidance system just could not cope. This was not merely an academic experiment. In its original conception the beam-rider missile required a separate radar to fix on each target, and if there were many targets a defensive system could easily be swamped. RAE had had some success in making several missiles share a radar, but many questions remained about the reliability of the system under an attack. British thinking was turning towards homing guidance, and a long investigation into beam-riding using the flawed RTV1 was clearly not worthwhile. After two stepped beam-riding attempts failed miserably early in 1955, SAD decided there and then to abandon all further work in that direction. It was not an easy decision as RTV1e rounds were still being manufactured under the Fairey contract, but enough was enough.

The rest of SAD's work on RTV1 continued, including the aerodynamic trials, the proving trials of a modified control system, and finishing the investigation into the troubled RTV1 propulsion system, which was now nearing a solution. There were also some successful RTV1f trials to check out the Range instrumentation to be used in forthcoming interception trials. But by the close of 1955 the decision had been taken that the long commitment to RTV1 should cease by mid-1956. As if sensing its coming demise and making amends for past sins, the rocket behaved very well at the end. The last firing of all came on 13 July 1956 and was a successful RTV1db round in the aerodynamics program. At the end of the year the whole project closed after nearly a decade in which large teams in both countries had devoted their energies to an outmoded guided weapon that was never reliable as a test vehicle. Nevertheless, it had been a good learning opportunity for the Australians. They had come to grips with guided weapons technology and aerodynamics, and laid the groundwork for their later vehicles such as sounding rockets for upper atmosphere research. Further, the experience with RTV1 simulation led to a great expansion of the techniques of guided weapons modelling.

SAD continued to work on the problems of the CTV5 series I test vehicle. RAE had transferred to it an investigation into the repeated failure of both the first and second stage boosts to separate properly at burn-out. SAD, which until then had been more or less the 'hands and feet' of RAE in CTV5 trials at Woomera, analysed the dynamics of separation and showed that the problems were caused by flutter of the fins fitted to the boost. These fins were very large to stabilise the unguided test vehicle in early flight, and thus were more prone to flutter than small fins. After special flight trials in 1956 SAD proposed that the CTV5 design be modified. An officer from SAD went to Britain in June 1956 to discuss these modifications and the future CTV5 series I program. The upshot was a decision to cancel any further work on series I, as an economy measure. Despite nineteen firings at Woomera in the four years between 1953-56, very little in the way of useful data on aerodynamic control had been forthcoming, not only because of separation failures but because the instruments fitted to the dart were not accurate or reliable enough. Such experiments would be better done in the large supersonic wind tunnels that were by then becoming available. Another factor in the decision was that Britain had by now turned its attention to upper atmosphere sounding rockets, as part of its commitment to the International Geophysical Year. A new vehicle had been developed, first known as CTV5 series III—a misnomer, as it was not a control test vehicle at all. Although like the others it was unguided and used solid propulsion, it differed not only in purpose but in its subsequent history. Under the more familiar name of Skylark this sounding rocket was fired over Woomera on hundreds of occasions over the next twenty years.

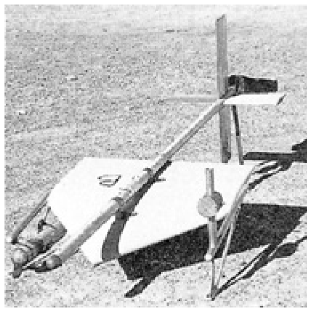
AIRBORNE RECOVERY

The end of the recovery program also came in 1956. This had started with the simple method, mentioned earlier, of using a radio-controlled charge to break up the missile in flight, causing it to tumble and so slow down, and then deploying a parachute to bring the instrument package back to earth intact. The jolt when the package hit the stony ground of the Range nevertheless damaged the instruments, and though nose spikes to cushion the impact had some effect, the recovery mechanisms still took up valuable room in the cramped interior of the rockets. Early in 1952 Chief Superintendent Harry Pritchard suggested that some means should be evolved of snatching the falling spent missile in mid-air. Tom Pearson, a British scientific officer, headed the team tackling this assignment, which Pritchard initially described to him as 'somewhat crazy and difficult'.[21] In the Pearson



Tom Pearson's schemes for recovering spent missiles while still in flight, using a drogue parachute in the missile and an intercepting aircraft with paravane.

scheme the falling missile was intercepted by a specially equipped aircraft. At the end of the active part of the trial, the missile released a small drogue parachute on the end of a long cable to slow its speed to about 60 metres a second. Meanwhile the recovery aircraft was approaching the point of interception, which typically was at 5000 feet. The aircraft carried an optical sight to assist in the final stage. It was also towing a long cable, held out sideways from it by a paravane, or type of kite. Near the paravane end of the cable was a grapnel. With some skilled flying the aircraft was flown across the path of the descending missile so that its own sweep cable hit the parachute cable, the two slipping over each other until the latter snagged on the grapnel, catching up the missile.



An experimental paravane on the ground.

There were two alternatives from this point. The simpler case was when the missile could withstand a moderate shock. In this case the paravane cable was given two weak links: one where it joined the aircraft and one where it joined the paravane. Under the shock of impact both severed, leaving the length of cable free with the missile swinging from its end. But the paravane cable was also joined on the inner side of the weak link at the aircraft end by another cable to a large parachute packed into a canister under the aircraft's tail. This parachute was dragged out and lowered fairly gently to the ground the spent missile dangling from the two cables.

The airborne recovery team's leader Tom Pearson. (RAE)

The alternative was used when the missile had to be recovered without any impact at all. Here there was only one weak link, which detached the paravane on the impact with the missile cable. At the aircraft end the paravane cable ran round a constant friction winch, of the sort used for the snatch pick-up of gliders. The winch cushioned the shock of impact, feeding out more cable while the missile was accelerated up to the aircraft's speed. Then the winch wound in the cable until the grapnel holding the missile cable was drawn into the aircraft. Next, the missile cable was attached directly to the aircraft via a weak link, and all was ready for the transfer stage. On the ground, stretched across a gully, was a cable system with shock absorbers at each end, consisting of a great number of bungee elastic cords. The pilot flew low until the missile cable dangling below the aircraft hit the ground cable suspended between the 'goal posts'. Again the two cables ran across each other until the missile was snagged: the weak link then broke it away from the aircraft, leaving the missile swinging above the ground absolutely intact.

The process sounds alarming, and certainly it took a long time to make it work safely. Designing a paravane which would fly on a parallel course and could be made airborne without endangering the towing aircraft was very difficult. During take-off the winch operator had to be ready instantly to sever the line, for on occasion the paravane flew in front of the aircraft or even encircled it, wrapping it in steel cable. Meanwhile after many experiments at Lake Hart a missile was safely transferred to the ground rig, set up in one of the gullies leading to the saltpan. The Beaufighter which had been used for all these experiments could not carry a winch heavy enough to deal with the missiles likely to be recovered, so a Dakota was obtained with a heavy duty American winch already fitted. But about this time, early in 1957, the whole task was cancelled because the cost of rockets had fallen and the effort required to recover them quite intact was judged too great. The recovery team was disappointed after all their labours, but they had shown that every phase of the technique worked even if they had never applied the entire sequence to one rocket. The best achievement came on 13 December 1956 when the recovery crew snatched an RTV1 from mid-air over Range E. The second parachute deployed properly and the rocket floated to the ground with little damage.

FAIREY VTO MODELS

Some of the other early trials at Woomera involved vehicles even more frankly experimental and tentative than the work on RTV1 and its offshoots. One example was the Fairey VTO models, which came to Woomera in 1951.

Some years earlier, in 1946, the Fairey Aviation Company was working on a fighter aircraft able to take off almost vertically under jet or rocket propulsion, either from an aircraft carrier or from the deck of other kinds of ship. Two benefits were seen. One was the quick response time, and the other was that vertical take-off would eliminate the need for a conventional undercarriage and thus save its weight. (The landing procedure is unclear; perhaps it was to have been managed by some skid or roller arrangement.) Official reactions from the government were dubious, but nevertheless Fairey was given a contract in July 1946 to build and test some half scale unpiloted VTO (vertical take-off) models. By the end of the year Fairey had on its drawing board a design for a rather tubby little delta winged aircraft with a wing span of 3 metres and a body only slightly longer.

Six of these airframes were built in 1947. The liquid fuel rocket engine to go in them took a great deal longer to develop. The VTO would be flying at such a high angle and so slowly to begin with that the aerodynamic surfaces could have no effect. The flight control therefore came from giving the rocket engine two separately movable combustion chambers, one for pitch and the other for yaw control. The rocket motors burnt two fuels, methyl alcohol and hydrazine hydrate, in concentrated hydrogen peroxide (HTP). These were the same dangerous propellants used by the Germans under the names of 'C-Stoff' and 'T-Stoff' in their wartime rocket planes, and they had been known to dissolve the pilots where they sat before they could get out after a crash.

The VTO models arrived at the Range some five years later with a rather tarnished reputation. An early production model had been tested in July 1949 from a tank landing craft anchored in Cardigan Bay, Wales. The first flight had arched upwards and then dived into the sea on launch; the second, in November, lasted a little longer before the autopilot failed, causing the model to roll violently and then corkscrew into the sea. These trials had used a temporary solid propellant motor. The first test with the bi-fuel liquid engine came in April 1950. The engine burnt well, but the craft started to roll shortly after it levelled out in horizontal flight. At the end of the trial it settled gently into the sea under a parachute but promptly sank, despite having its wings stuffed with ping pong balls to give it buoyancy. These erratic trials were a perfect object lesson in the value of the Woomera facilities. The plan was for the VTO model to rise almost vertically from its launcher to a height of some 3000 feet and then fly straight and level. The models only had a range of 20 kilometres at most, but even so they could not be launched on land in Britain. Enough room was available out at sea at Aberporth (48 kilometres) but the intractable problem of recovering the remnants was a major obstacle. It was time for Woomera, and another four vehicles were ordered from Fairey to supplement what remained from the initial purchase of six.[22]

When the Fairey VTO team came to Australia early in 1951 they were based at their Special Projects Division in the Contractors' Area at Salisbury and had the use of an air-conditioned workshop at Range E. The VTO models assembled there for the last time had already undergone the process twice, once at Fairey's English plant and again at Salisbury, and the repetitions did not improve the reliability of the delicate gyros. Then they went out to the launching ramp for the final checks in the heat and the dust. One day the Range Superintendent came over in a helicopter, showing a visitor the launcher from above. He took the Bristol Sycamore in too close, blasting dust into the exposed VTO mechanisms and reducing the Fairey team leader to speechless rage.

The heat was intense on the Range that summer. The Fairey staff working out on the ramp were fully exposed to the merciless Woomera sun and the accompanying torment of myriads of bush flies. The team started to work at night for coolness, but then insects were attracted to the floodlights in their coruscating millions, swirling wildly about before falling incinerated to the launcher platform.

Attempts to launch the VTO began in February 1951 but were delayed repeatedly.

▲ This 1983 aerial view includes most of the Salisbury (WRE) grounds. In the foreground are the HQ area (*left*) and Penfield Avenue (*right*).

▼ This old building, formerly Sturton Methodist Church, lies inside the Salisbury grounds. It has been restored and is again used for services.

▲ Woomera, a man-made oasis in the treeless, stony, semi-desert of the Arcoona Plateau. The distant salt lake is Island Lagoon.

▼ Looking towards the civic centre of Woomera—a 1975 photo
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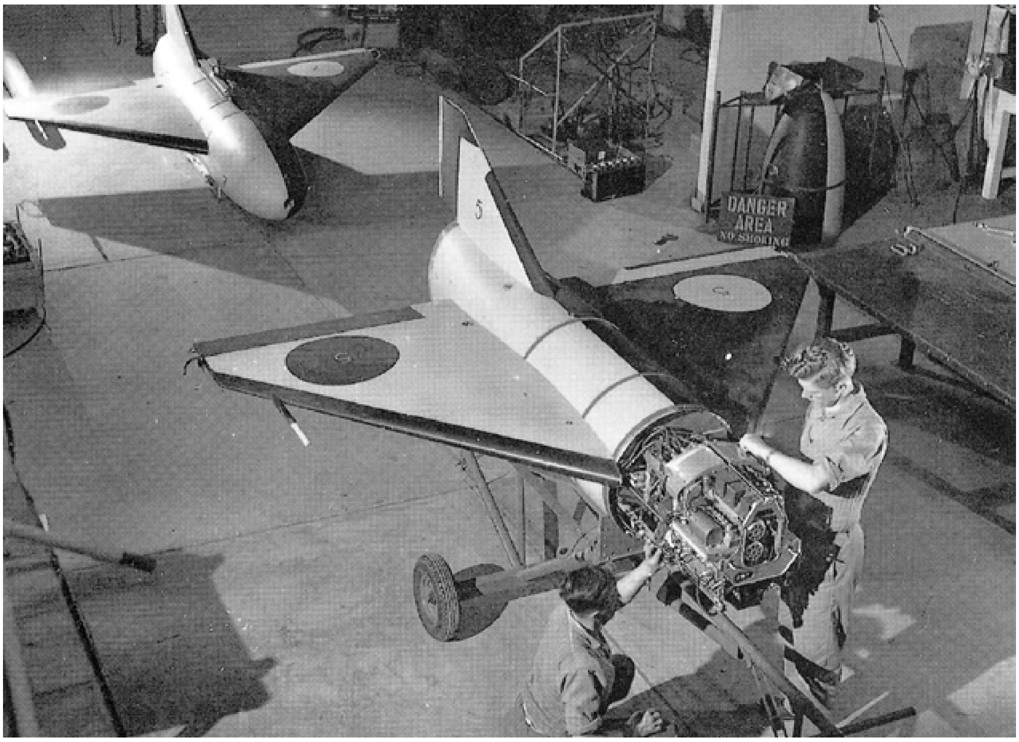
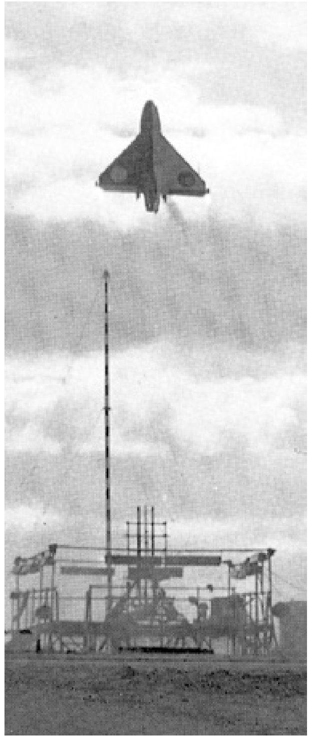




Above left: The Fairey team preparing a VTO model in the Range E workshop.

Above: The VTO is launched.

On 28 May, model number 7 at last took to the air. The cheers were as brief as the model's flight. It veered sharply to the right as the servo controlling the yaw combustion chamber failed, exploding violently on impact and scattering fragments in all directions. When the dust subsided and the quietness of the desert returned the watchers could see the two combustion chambers, still joined by flexible tubing, swinging from the overhead power lines. Because of the dubious performance of the vehicle small slit trenches were dug alongside the observation posts. The second flight on 10 August began well with the model climbing and flying into cloud. The watchers could hear it motoring around invisibly and the Range Safety Officer began to get worried. 'Evacuate posts!—No, no, cancel that,' he called a couple of times. Then, instead of levelling out and flying down-range as intended, the model reappeared diving steeply in the direction of the launcher and crashed some distance to the rear of K2 and K3 instrumentation posts, manned by Computers Rhonda Price and June Gill. When Gill decided to abandon her camera and seek the trench, too late! It was already occupied.

The three following trials were a little more successful, but for safety reasons the angle of launch had been reduced to 45 degrees which rather reduced the value of the exercise. The last surviving model was eventually handed over to the Department of Supply for exhibition purposes on condition that no mention be made of the vertical take-off feature. About all that can be said is that the firings had given Range and contractor staff useful practice in handling dangerous fuels under difficult conditions. Two telexes of 10 April 1951 make plain that the VTO aircraft was doomed before it ever flew at Woomera. The word from UKMOSS was that Fairey was not moving quickly enough towards the supersonic full scale version and, in any case, the original contract had been placed in a slack period and now there was more urgent work to do. MoS was inclined to cancel. A telex went from the Melbourne headquarters to Chief Superintendent Pritchard of LRWE, to discover if he thought any local political fur might fly if the VTO project were scrapped. Pritchard answered simply, 'no objection.'[23]

PROJECT E

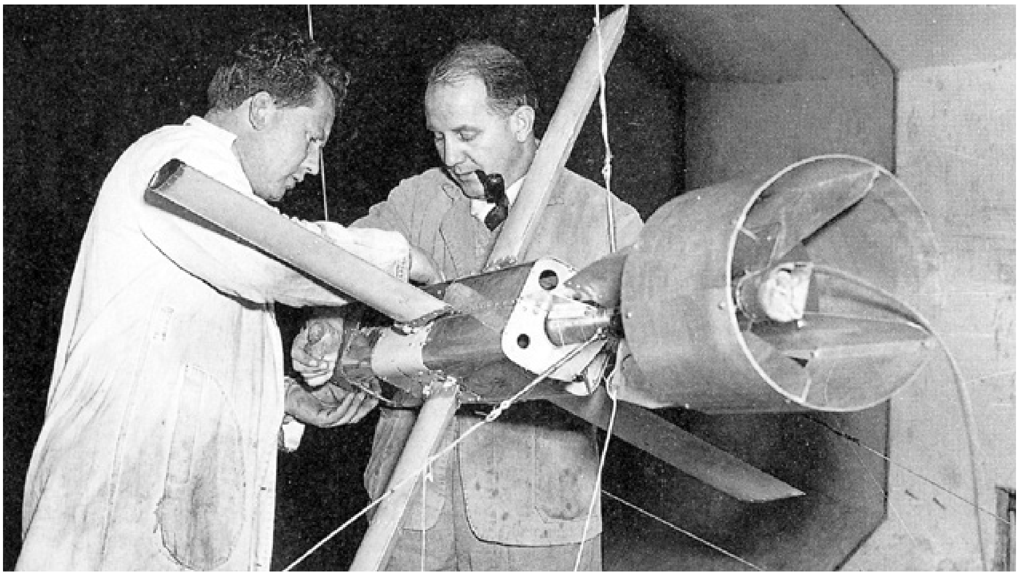
As later chapters will amply demonstrate, cancellation was the fate of many weapons. Not all of them were projects sponsored by Britain; in fact the very first Australian offering known as Project E ended in cancellation, much to the disgust of everyone involved. Project E never got beyond the test vehicle stage, but was intended to lead to a small anti-tank guided weapon, portable enough to allow two infantrymen to assault a tank.

The stage had been set in 1949-50 with the reorganisation of the Department of Supply laboratories, when LRWE and the older Aeronautical Research Laboratories (ARL) and Defence Standards Laboratories (DSL) had been brought together under Butement, when he was appointed Chief Scientist in April 1949. One of the reasons for the reorganisation was to build up from scratch an Australian guided weapons industry. After discussions in Britain, Butement decided that it would be best to start with something not too ambitious, and a British Army requirement already existed for a light anti-tank weapon. Unfortunately the Australian Army had no matching requirement, claiming to see no need for such a weapon.[24]

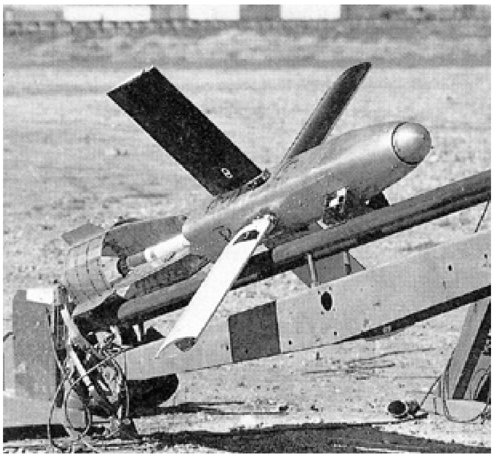
In August 1950 Butement assigned to ARL the development of Project E. It was a far cry from ARL's traditional field of aircraft aerodynamic research, but at least it was an opportunity to get into a new role of developing guided weapons. This one was to be a simple robust missile, light enough for two men to carry with its associated equipment. A maximum range of 1.4 kilometres was specified, with a desirable minimum after the necessary 'gathering' phase of 270 metres. It would be fitted with a small shaped charge warhead. For a long time tanks had been surrounded by sufficient armour plate to make them invulnerable except to the heaviest calibre of guns. The German development of shaped charges during the war meant that a small rocket could carry enough explosive to punch a small hole through quite heavy armour and channel a stream of molten metal inside.

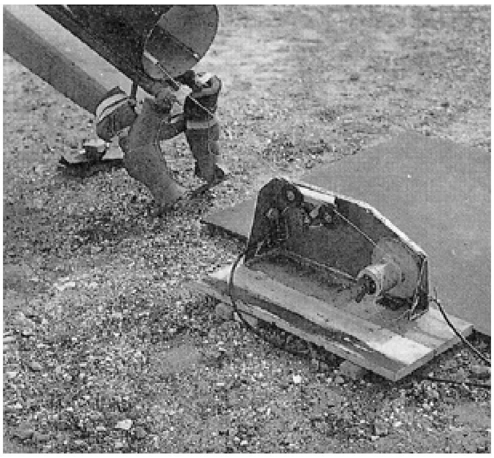
Dr J. R. Green of ARL (later of HSAL at Salisbury) was given the design work and within a week he had a model of a wing body arrangement ready for testing in a wind tunnel. His approach was to make the weapon cheap, simple and sturdy so that it would be reliable and quickly prepared for firing. For simplicity's sake the missile had no roll stabilisation but rolled freely around its long axis as it flew. A commutator device controlled by a spring-operated gyroscope compensated for any roll, and ensured that the command signals worked the correct fin out of the four, which were arranged around the body in cruciform fashion. After firing the missile the operator guided it visually to the target by means of a joystick, sending the steering signals along a wire which trailed behind it in flight. The advantage of a wire was that the control signal could not be jammed or confounded on the battlefield, and it avoided the need to fit a radio receiver with its power supplies. In fact the missile had no electrical power source of its own. The voltage signals passing down the wire opened or closed valves which allowed a variable flow of air to be scooped up from the outside. This rushing air had enough kinetic energy to work the servo mechanisms which moved the wings in pitch and yaw. The German X-4 and X-7 wire guided weapons had provided some of the initial ideas.

The German weapons had used two steel wires, but the rather poor conductivity of steel had meant giving the missile an internal battery. The Project E designers wanted to eliminate the battery to improve the storage life of the weapon, so they experimented with a wire made of a cadmium-copper alloy which was both strong and highly conductive. It had to be prepared carefully, with its insulating enamel baked on cautiously at a low temperature to avoid annealing and so softening the wire. Various adhesives had to be tried to hold the



Dr L R. Green (*right*) setting up a Project E model for a wind tunnel test.





Far left: A Project E test vehicle on its launcher at Range G. The circular air intake in the nose is visible.

Left: A rear view, showing the control signal wire passing from an aluminium tube to the tensioning device on the ground.

wire in place, as well as different winding methods, including pre-twisting to compensate for twisting and kinking when the wire was dispensed. Only after many tests, some of which gave contradictory results, were the important factors determined. Eventually the single strand wire was replaced by a four conductor soft copper cable in a woven nylon sheath, and this was refined further over the short life of the project.

Responsibility for Project E moved several times as the centre of design interest shifted. A. j. Oxford of the Electronics Research Laboratory, R. W. Cumming of ARL and Dr }. R. Green, first of ARL and later of HSAL at Salisbury, all directed aspects of the project. It was Dr Green who directed research and experimental firings at Woomera over the critical period of 1953-54 when the vehicle changed from its initial experimental form to take on the more streamlined shape of Project E Mk 2. Extreme urgency had marked the project from the beginning and many decisions had had to be made solely on the basis of engineering judgment, unsupported by research or simulator studies. Simulator work in the UK afterwards tended to support those judgments. By this time the requirements for an anti-tank weapon had changed and also split into two. The British War Office had issued two specifications. One was similar to the concept around which Project E had been designed, except that a lighter 4 kilogram warhead was specified instead of the 7 kilogram one adopted for Project E. The other, issued in March 1952, was for a much heavier weapon to carry a 27 kilogram squash warhead, and with a range of 3.6 kilometres. At this stage the Ministry of Supply wanted both weapons and they also wanted Australia to develop the heavy as well as the light one. By mid-1952 the Government Aircraft Factory in Melbourne had been asked to design a new anti-tank developmental weapon, at first named Project J and later Malkara. Its subsequent history is described later. Project E had a head start and work on it continued, but by early 1953 it was regarded as a test vehicle for either the light or the heavy specifications. The Project E rounds being built by Fairey were later referred to as Experimental Test Vehicles (ETV).

During 1954 HSAL moved from its quarters in what is now the Edinburgh air base to buildings to the north where the big new high speed wind tunnel was being built. The wire problems were well on the way to solution. The wire ran off from a spool at the front of the missile and was led to the rear through an aluminium tube, so that as the wire ran out the loss of weight balanced that of the expended propellants, thus maintaining the centre of gravity. The wire was coated with a sticky mix of resin and oil to hold it on the spool so that two or more turns would not be pulled off together, and also to provide some lubrication in the dispensing tube. The successful mix happened to be the one normally applied with arsenic added to the flypapers of the day. The pneumatic actuators and other control elements were also refined and on 6 December 1954 HSAL prepared to fire six of the ETV Mk 1 version to see if they could hit a 5 metre square target at a distance of about a kilometre. The vehicles had shown some faults during testing but the launching crew hoped these had been rectified. The first round went high and the pilot failed to get it back on target. A miss. The light was fading but the wind had dropped to almost nothing as the wavering second round, number 255, streaked with smoking flares towards the target on the skyline—a diagonal cross in a black box. It rose a little above the line of sight; the pilot quickly brought it on course and then guided it into the wire mesh barely a metre from the very centre, leaving the control wire trailing through the ragged hole. So it was that Reyn

Reyn Keats, first to hit the target.

Keats, formerly a bank clerk and later a Professor of Applied Mathematics, became the first man at Woomera to fire and guide a missile to its target. His careful and methodical work had done much to bring about this moment of triumph. The celebrations in the Senior mess that night were notable for a riotous baseball game played with champagne bottles.

With Keats in the old General Grant tank, used to protect the pilot from mishap, was the reserve pilot E. G. (Ted) Hayman who had improved the original Project E simulator and used it to train pilots and to explore different control systems. Hayman remembers, with regret, that he never got the chance to fly the missile. Keats fired the last four of the test rounds on the 8th, and two of them were near misses. After the Christmas stand-down the Project E team, having proved its missile worked, went back to developing the ETV Mk 2. But the outlook for the light anti-tank weapon had started to look gloomy. The War Office had made up its mind that only the big 27 kilogram warhead would give a '100 per cent kill probability' against a tank. The Australian Army still declined to be interested in an anti-tank guided weapon, and so Supply could not justify continuing with Project E. Further development of the ETV was stopped early in 1955 and the capable Project E team disbanded, with its members either transferring to other projects or, like the leader Dr Green, leaving WRE altogether. The irony is that a few years later Vickers in the United Kingdom began to develop privately a portable anti-tank missile which was very similar to the abandoned Australian Project E, and the British Army ordered 12 000 of this, the Vigilant, after its acceptance trials in 1964. It also sold widely overseas.

TAKING STOCK OF PROGRESS

If one surveys the course of joint project work in guided weaponry at the end of 1956, it has to be said that the outlook did not look too promising. That year had seen the cancellation of the first small guided weapon to be designed and built in Australia, and RTV1 too had come to the end of the line. Yet 1956 was also the year when the British government finally decided to disband Anti-Aircraft Command after tests at Woomera in 1951-53 using the most advanced gunnery with simulated fire against high altitude bombers. The results showed conclusively that the gun was entirely ineffectual against aircraft taking evasive action above 30 000 feet.[25] Despite the fits and starts of the work done so far, nothing changed the certainty that the future armament of every military force would be dominated by guided weapons. Just how Woomera helped the first generation of British missiles to reach the point of becoming reliable weapons, available to the services 'off the shelf', is taken up in a later chapter.

Notes and Sources

1. G. R. Gleig, *The Subaltern*. J. M. Dent, London, 1915. First published 1825.
2. Anon, 'The rocket racket', School of Artillery, Larkhill, UK (August 1946). Unpublished.
3. Methanol (methyl alcohol) fuel replaced petrol in LOPGAP in July 1947, well before it came to Woomera as RTV1. At a slight cost in thrust, the methanol had a little water added to it to reduce the burning temperature and hence erosion of the combustion chamber, especially in the venturi throat.
4. The following table gives the various RTV1 configurations fired at Woomera:

TYPE	SUSTAINER ENGINE	FLIGHT PROGRAMMER	ROLL CONTROL	LATERAL CONTROL	GUIDANCE RECEIVER	REMARKS
RTV1 x	No	No	No	No	No	Dummy Round
RTV1 x0	"	"	"	No	Yes	Receiver test dummy round
RTV1 x2	"	"	"	"	No	Lengthened dummy round
RTV1 a	Yes	"	"	"	"	Hot propulsion round
RTV1 a2	"	"	"	"	"	Ditto with higher thrust motor
RTV1 b	"	"	Yes	"	"	Hot Roll-stabil-ised round
RTV1 c	"	"	No	"	Yes	Receiver test with motor exhaust plume
RTV1 d	No	Yes	"	"	"	
RTV1 db	No	No	Yes	"	No	Cold roll-con-trolled round
RTV1 e	Yes	"	"	Yes	Yes	Beam riding round
RTV1 f	"	Yes	"	"	No	Hot, control programmed round

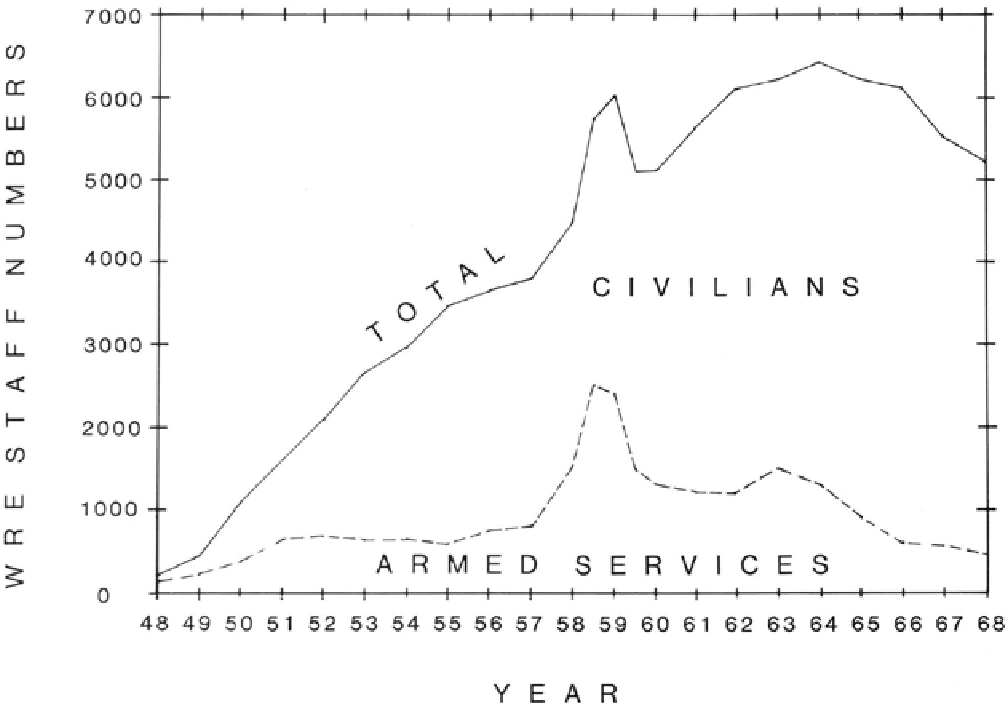
'Dummy' rounds had boost motors but no sustainer, and had fixed fins. 'Cold' rounds had no sustainer but had moving fins and were fired for early tests of the guidance and control systems. 'Hot' rounds had both boost and sustainer motors.

5. The author is indebted to E. C. Montgomery for his contribution of August 1984 on which this section and later sections dealing with RTV1 are based.
6. As told in the previous chapter, R. P. Bonnell had collected kinetheodolites, Vinten cameras, radars and specially built plotting tables for the bomb ballistics range. He ordered generous quantities and this spare equipment was the basis of the original instrumentation at Range F and Range G until the special gear arrived.
7. Norman Coles, 'A suggested programme for training personnel of the Australian range in the firing of the RTV1.' RAE Technical Note GW 32 dated November 1948.
8. Minutes of the 15th Meeting of Superintendents of 18 February 1949. File SA5091.
9. This account of the activities at Port Wakefield is drawn from a contribution by R. F. Treharne written in June 1980. See also R. F. Treharne, D. J. Mudgway, D. S. Robertson & O.H. Turner, 'Reflection doppler and radar trials. Port Wakefield, February 1949.' Electronics Group LRWE: Note LRWE-E/T-3. DRCS library ref. SW-M- 38315-U.
10. Contribution dated 30 March 1985 from Denis Arnold. File T6345/2/3.
11. Formerly the old Munitions Factory's Fuze Area, by which name it continued to be known for some years.
12. Arnold.
13. C. Bayly, 'A suggested programme for the manufacture and further development of RTV1 in Australia.' LRWE Technical Note No T/N 1 dated 8 June 1950.
14. Minutes of 7th meeting of the Board of Management of 7 July 1950.
15. J. A. McMullen, 'Final report on Australian manufacture of RTV1e.' Salisbury: Fairey Aviation Company of Australasia (August 1956).
16. Details taken from a contribution of P. M. Twiss written in September 1981.
17. The dart was fitted with a simple 'scratch on celluloid' recorder and a telemetry sender to record drag and acceleration components. Kinetheodolites and doppler on the ground measured position and velocity.
18. 'Three injured at Woomera,' Sun (Melbourne), 2 October 1953. Benson returned to RAE and, with the aid of a guide dog, continued to work there until he retired.
19. The 'Q' trials in the UK were a politically necessary demonstration that RTV1 could hit a target, before RAE was given funds to start the development of a better missile—something RAE had decided was necessary because of RTV1's many defects. An attempt on 3 February 1954 failed when the warhead replacing the usual telemetry package on a RTV1e exploded prematurely. The attempt of 4 April succeeded when a slow moving drone was guided along a suitable

intercept path just after the missile was fuelled. (RTV1 had to be fired within two minutes, or else too much of the LOX evaporated.) The guidance systems worked on firing and the warhead exploded close enough to tumble the plane out of the sky. It is very possible that the target hit the missile.

20. The SAD abbreviation was seized on for use in the annual Divisional parties, and its staff became the SADSACS, after a comic strip of the day.
21. Letter dated 9 October 1979 from W. T. S. Pearson to E. C. Montgomery. File T6345/2/10 part 1.
22. It is not clear why four were needed; the records show only three trials undertaken.
23. This account of the VTO trials at Woomera is indebted to a contribution by J. W. Dodds written in March 1981.
24. In an interview of 23 September 1983 Butement claimed that this evaluation had been made by Lt Col Edgar, who had been the first Superintendent at Woomera until prematurely recalled at Butement's insistence because of his reluctance to work with civilian scientists.
25. These tests were held on Range G1, an extension of Range G. This site was equipped with early warning and fire control radars plus the most advanced predictor then evolved. The Lincoln and Canberra bombers with their experienced RAF and RAAF crews did their best to drop practice bombs on the target while trying to keep the straight and level bombing run to a minimum to defeat the fire control system. The predictor output was recorded and later analysed to compute where the shells would have burst if heavy anti-aircraft guns had been under the predictor's control and actually fired. Information from Lt Col E. J. H. Howard in a letter dated 6 June 1986.

Part II: The Years of Achievement



This graph shows the rapid growth of WRE, and its predecessors, up to the major reorganisation of 1968. The short-lived peak around 1959 was caused by a RAAF build-up at Edinburgh and subsequent transfer to non-WRE work.

The headquarters of the Aeronautical Research Laboratories at Fisherman's Bend. Melbourne.

12 The joint project in its maturity, 1950–65

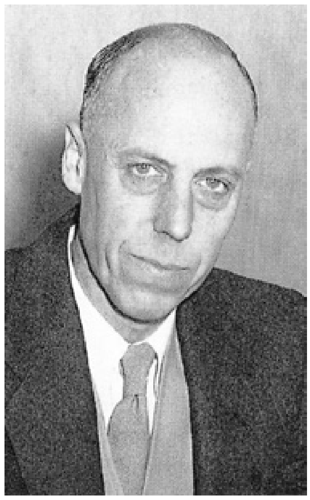
CONSOLIDATION AND AMALGAMATION AT SALISBURY

After a rather shaky start the Long Range Weapons Establishment (LRWE) saw rapid, almost explosive growth for nearly two decades, peaking at more than 6000 employees in 1964. Not all of this staff was doing work for the joint project, but such work did absorb the largest proportion of WRE's efforts for many years and it constituted easily the biggest sustained program of research and development anywhere in Australia.

No sooner had the pace of activity at Salisbury started to quicken than the Australians became intent on integrating their own fledgling defence research efforts with LRWE. The first step was simply to bring together under a common administration the existing laboratories: the new Establishment at Salisbury and the older Melbourne establishments of the Defence Standards Laboratories and the Aeronautical Research Laboratories (formerly CSIR's Division of Aeronautics). The R&D Division of the Department of Supply ran these three facilities under the collective title of the Australian Defence Scientific Service.

The next step was to expand Australia's role in guided weapons research. In 1951 some of the activities of the Aeronautical Research Laboratories (ARL) were transferred to a new High Speed Aerodynamics Laboratory, split off from ARL specifically to undertake classified work. A new Propulsion Research Laboratory was founded to work on rocket motors, and an Electronics Research Laboratory to work on guidance and control. All three of these new laboratories were housed alongside LRWE in more of the vacant munitions factory buildings at Salisbury. In 1953, for administrative reasons, the Propulsion Research Laboratory and the Electronics Research Laboratory were combined in a single entity, the Chemical and Physical Research Laboratories. In January 1955 the separate entities on the Salisbury site—the Chemical and Physical Research Laboratories, the High Speed Aerodynamics Laboratory, and LRWE—were combined under a single title: the Weapons Research Establishment (WRE). Amalgamation was now complete. At the head of WRE was placed a single Controller, answerable directly to Chief Scientist Butement.

The amalgamation was more than a matter of administrative convenience, though eventually, no doubt, the pressure of logistics alone would have brought the two groups of facilities at Salisbury under one umbrella. They needed so many of the same support services—airfields, wind tunnels, test rigs, workshops, stores, registries, security, fire service and so forth—that any other procedure meant wasteful duplication. No, much more significant was that the creation of WRE marked a distinct Australianisation of the joint project. This is very apparent when one examines the restructuring of the top posts at Salisbury. At the time of the amalgamation the Chief Superintendent of LRWE was an Englishman. His predecessor had been an Englishman too and a London appointee to boot. In 1955 all this changed. The post of Chief Superintendent was abolished. Symbolic of the fact that the new Establishment was now firmly an Australian entity was the choice of the first Controller. He was H. J. (Harold) Brown, a lean dapper man in his mid-forties who had a varied career behind him including being the foundation Professor of Electrical Engineering at the NSW University of Technology. For the last four years he had been Controller of Research and Development in the head offices of Supply, looking after the Australian research laboratories. Brown was an experienced manager, but in the context of the time the main point about him was that he was Australian through and through: Sydney born and bred, he had spent the whole of his impressive career at home. This attribute was continued with his successors. In 1958 Brown moved back into private industry and



H. J. Brown, shortly after he took over at Salisbury.

Dr C. F. Bareford.

R. W. (Bill) Boswell succeeded him under the title of Director. In 1965 Dr M. W. (Don) Woods succeeded Boswell until the office of Director disappeared in 1978.

At the reorganisation two Deputy Controllerships were created below Brown. One was in charge of Trials and Instrumentation (Dr C. F. Bareford) and one in charge of weapons research and development (Dr F. A. Fox). Also reporting directly to Brown were three superintendents, responsible for Woomera, the air component, and administration. At this time Boswell, destined soon to become the powerful and popular Director of the Establishment, was a superintendent but he was not one of these three; he was responsible for the trials program and adding facilities to the Range as required. He was answerable to Deputy Controller Bareford.

The birth of WRE was all the more painful because of a parallel series of events involving the man who had formerly been Chief Superintendent of LRWE.[1] This was Dr C. F. (Chris) Bareford, an electronics engineer, who in June 1953 had come from being the Director of the Mullard Research Laboratories in England to take over from H. C. (Harry) Pritchard. At the amalgamation he might reasonably have looked for the Controllership of WRE; instead he suffered the demotion, in his own eyes anyway, to Deputy Controller. Bareford was a forceful and complex personality, given to extreme swings of mood. Apart from his technical competence, which was great and unquestioned, he was so interested in the politics of his new post and so fond of influencing events and people behind the scenes that he acquired a reputation of being something of an intriguer. Although on moving to Australia he had technically become a public servant of that country, he did not conceal his sentiment that LRWE should be 'independent'. His position was defensible enough. The Establishment was jointly funded and so one could argue that its Chief Superintendent should answer to CUKAC in London, not to the Australian Chief Scientist in Melbourne. To his enemies, though, it signified only that he wanted the British influence on joint project policy to continue as the dominant one. There is little doubt, too, that Bareford fell into the trap which Evetts had so astutely avoided. According to gossip he made no bones about coming to Australia to show 'the colonials' how to put some stuffing into a defence research organisation.

Right from the time of his appointment Bareford's trenchant views brought him into frequent collision with the Department of Supply: first with Dr Ben Gates, the Controller responsible at headquarters for LRWE, and then with the Chief Scientist himself. It remains unclear just how far this friction hastened the amalgamation—the Australianisation—of Salisbury. Certainly it did not cause it. The shift of control was as inevitable as such things can be, and assuredly would have gone ahead no matter how docile Bareford had chosen to be. But, his attitude being what it was, it did have its conveniences as far as the Minister and the Chief Scientist were concerned, for it dispensed with the need for lengthy consultations. The administrative changes could be done by fiat.

Matters came to a head around Christmas 1954 when Bareford took a British paid trip home without notifying the Department. (Which strictly he did not have to do as he was on leave and the odd courtesy flight home was a common privilege for the upper ranks of British expatriates.) However, once in London Bareford wasted no time in airing his resentment over the forthcoming turn of events at Salisbury. When he heard what Bareford had been doing, Butement decided to reduce his autonomy. He also decided that after the amalgamation the new Controller had better be based in South Australia to keep things on a tighter rein. Harold Brown moved over to Salisbury on Monday, 17 January 1955, and on the evening of that same day the unsuspecting Bareford landed at Mallala after his return flight from England.

Early next morning came the showdown. Brown went to Bareford and in a dramatic and painful scene told him that he had explicit instructions from the Minister to take charge and to move into the Chief Superintendent's office within two hours of his arrival. Bareford's title of Chief Superintendent was removed and replaced by that of Deputy Controller in charge of Trials and Instrumentation alone. Brown recalls the occasion vividly:

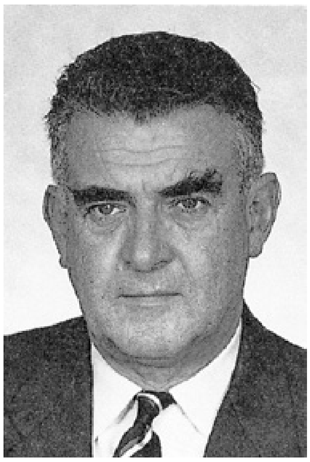
> It was a very unpalatable situation but I went in and told him that and then I said: 'I'll go round the Establishment to see people and when I come back at eleven o'clock I will be taking charge of this room as my office.' He went white in the face and said various things I don't want to repeat. I just kept my cool and said: 'Those are my instructions. I'm not telling you myself; my instructions are to tell you that and I'm only passing them on.' When I got back at eleven o'clock he had moved out to the office next door where Bill Boswell had been and he'd found Boswell another office somewhere else.

The next few months were a dreadful period. One wonders why Bareford stuck it at all, rather haughty as he was and trained by his father from boyhood to be a leader of men. His loss of face was great, and he had to nurse the bitter knowledge that his influence over the future evolution of WRE had disappeared for good. Still, Bareford was not entirely out on a limb at the new WRE. He had his supporters, although they backed him from mixed motives. Some admired his technical ability and found him a congenial boss. One of Bareford's good qualities was that he left his staff alone so long as they were producing, and this naturally appealed to the sort of engineer who was engrossed in his work and only too happy to keep clear of departmental politics. Some of Bareford's fellow Britons felt the tug of conflicting loyalties; they owed allegiance to their new employer, but they wanted Britain to continue as the dominant partner in the project, and Bareford was undoubtedly the Ministry's man. Some Australians, including Boswell apparently, were so wedded to the idea of WRE's regulating its own affairs, and so resented the on-the-spot control from Melbourne which Brown represented, that they were prepared to support the Englishman. (In another view, Boswell had embarked on a machiavellian plot to 'set up' Bareford by encouraging his notions of independence and his defiance of headquarters.) Bareford was an Anglican, and those interested in sectarian squabbles used him, with or without his assent, as their champion against the Catholic administrators at WRE who were reputedly infiltrating their co-religionists into the key posts.

With this support behind him, Bareford, who was nothing if not a fighter, took his case to the MoS representatives in Melbourne, to the Department of Supply and even to the chairman of the Public Service Board. His complaints grew so bitter that Brown—who was not having an easy time either; he and his family were suffering some ostracism—forced Bareford to get his personal permission before ordering any more tickets for interstate travel. The situation was of course inherently unstable. The climax came after a few months when Bareford was embroiled in a major row. Somehow it came to the ears of the Prime Minister himself that a rumour was abroad, alleging that funds for the joint project were being diverted into illicit uses elsewhere. Menzies ordered Howard Beale, the Minister responsible, to search out the facts. Beale investigated thoroughly but failed to uncover any irregularities. In his report to Menzies he essayed a guess at the source of the rumour:

> I strongly suspect that it comes from Dr C. F. Bareford, who until recently was Chief Superintendent, Long Range Weapons Establishment. Dr Bareford is an Englishman who was appointed to his position two years ago, and his record with the Department is one of trouble-making, intrigue and, I regret to say, untruthfulness and misrepresentation.[2]

Whatever the rights and wrongs of Beale's severe judgment, it was probably the last straw. Then or soon afterwards Beale gave instructions that Bareford should be told to resign or be dismissed. He resigned. Pleased no doubt to shake the dust of Australia off his feet, Bareford returned home to a long and successful career with the Vickers research establishment. His post was taken over by Boswell, who was now only one step from the top. In 1958 Brown's resignation to return to industry at last gave Boswell the Directorship. Over the next seven years—which was, incidentally, WRE's most glittering period—the big, square cut Bill Boswell with his growling voice and bushy eyebrows so dominated the Establishment that in the eyes of the public at least he *was* 'Mr Rocket Range'.



R. W. (Bill) Boswell in 1964.

Boswell was born in Carlton, Melbourne, in 1912, educated at the University High School and took his M.Sc. degree at Melbourne University in 1934. He worked first for the CSIR Radio Research Board and for the PMG Research Laboratory. During the war he helped to install the first radar in the ships of the RAN. After the war he had a spell as Senior Airways Engineer in the Department of Civil Aviation, and then joined LRWE as Principal Officer Electronics in 1948. His rise in LRWE was rapid: Superintendent Research and Development from 1949 to 1954; Deputy Controller Trials and Instrumentation from 1955 to 1958, and finally Director WRE from 1958 to 1965. After leaving WRE in 1965 Boswell went first to Canberra for four years as Secretary of the Department of National Development; then to London as a Deputy High Commissioner until 1972; then back home as Chairman of the Atomic Energy Commission. He died in his office at Lucas Heights one morning in February 1976, at the age of sixty-four.

Boswell was a man of immense ability, energy and charm. He was also a man of driving ambition who knew his worth and could have been happy nowhere except at the top. He drove himself hard but rarely showed much sign of strain. He had his own methods of dealing with it. Peter Twiss, an aerodynamicist who at that time was the Supply representative in the United States, recalls travelling around the country to one exhausting engagement after another:

> I can remember Boswell once looking at the back of his hand, rubbing his hand, and I asked, 'What are you doing?' 'See that, young Twiss?' he said. He had sort of red weals coming up. That means it's time to declare a Boswell Sunday.' 'What are you talking about?' 'A Boswell Sunday is when I go to bed at six o'clock in the evening and don't get up all the next day. And that's the indicator.' That I suppose was in the end the reason for his death. I can remember him saying when he was leaving the Deputy High Commissioner job: 'I want to do one more job and I'm going back to be head of the Atomic Energy Commission.' And I said, 'You're bloody crazy. You love this life. You'd only have to lift a finger and you could be Ambassador somewhere. Why don't you take it?' 'No, I want to do one more worthwhile job.'[3]

During the reigns of Bareford and Brown, Boswell was frustrated and unhappy, and intentionally or not he made life miserable for staff whom he suspected were ambitious to overleap him. Once he was especially cutting to Emlyn Jones, a protégé of Bareford's and another ex-Mullard engineer who had newly arrived in Australia. Boswell wrongly assumed that Jones was being groomed as Bareford's right-hand man, and at a party soon after Jones's arrival Boswell commented bitterly that the British newcomers were taking jobs that Australians could have handled. For some time afterwards Jones suspected that Boswell was trying to drive him out by diverting work away from him.[4]

Once Boswell had arrived in the position to which he had aspired for so long (and even those unfriendly to him concede that he was uniquely fitted for it) the disharmony ceased and the Establishment began to hum like a top. Boswell surrounded himself with his 'young men' whom he trained for key positions. Sometimes he required them to cut corners, but he never left them exposed. Once, for example, a visiting Minister insisted on having an executive's toy made. He wanted a 'decision maker' to put on his desk: really a generator of random pulses with a colourful display. Boswell asked one of his laboratory chiefs to have this thing designed and built on the quiet without any paperwork, and though Boswell did not exactly promise to take responsibility if the episode blew up in their faces, the man trusted him implicitly and did the job.

Miss MacDonald ('Miss Mac'), 1964.

To the Boswells' big house in Penfield Avenue came people by the score: military men, politicians, diplomats, scientists from all over the world. The style was kept informal and Mavis Boswell, alerted by 'Miss Mac', Boswell's private secretary, had the task of constantly feeding and lodging guests at very short notice. One of Boswell's most perfected tactics was to use the easy social gathering as a vehicle for resolving problems. He applied this tactic with great success to the visiting British teams. Before the decisive meeting he would take the visitors to his house for an evening barbecue, get everyone mellow with red wine and chops and then take the team leader into a special corner of the garden where they could have a nice long quiet talk and thrash out every point at issue. Those who watched Boswell using this technique swore that he never entered a meeting without having its outcome firmly decided in advance.

BRITISH REACTIONS TO THE AMALGAMATION

How did Britain's Ministry of Supply respond to the significant shifts in control over the period 1950-55? At the diplomatic level it had been careful to express no resentment at the first signs of Australia's independent moves. The foundation of the three specialised laboratories at Salisbury in 1951 received an apparently enthusiastic welcome in London. An aide-mémoire from the British High Commissioner's Office in January of that year argued that the problems of the new guided weaponry were so taxing that help at any level could only be useful:

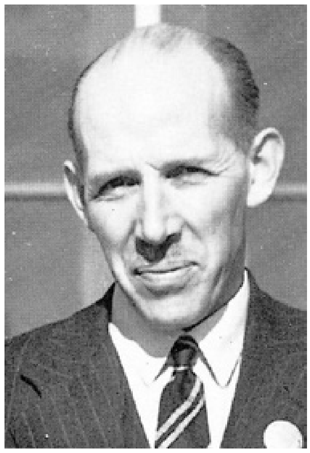
> It may be added that the development of guided weapons requires work in aerodynamics, propulsion and electronics fields. Difficulty is being found in the United Kingdom in securing the most effective liaison between workers in experimental establishments where these are widely separated. Geographical separation had little effect when the contributions of scientific workers were embodied in separate boxes which could be fitted in the comparatively large space of an aircraft and between which the crew of the aircraft provided a human link. In the case of the guided weapon there is no such human link and the various parts of the weapon must all work together perfectly. This demands in turn that the separate developments be

intimately associated. The proposal to set up research establishments for each of the above fields at the same location in Salisbury, Australia, appears, therefore, to offer Australia an unparalleled opportunity to make rapid progress in guided weapons work.[5]

H. C. (Harry) Pritchard.

Taken at face value this was all very cheering. But the real sentiments of those in the upper echelons of MoS, as 1951 gave way to 1952, were nowhere near as effusive. The Chief Superintendent of LRWE at the time was Harry Pritchard, who was not an Australian public servant but a MoS scientist on secondment to Salisbury. Pritchard's career had been in aircraft instrumentation, especially navigation aids, and just after the war he was chief of a Blind Landing Experimental Unit which developed techniques for bringing in aircraft in nil visibility. Before moving to Australia he had worked at RAE on control and guidance systems for missiles and had personally produced a mathematical basis for astronavigation in space. He thus had a thorough grasp of all aspects of guided weapons work, from research through to production. It is not surprising that this talented man quickly found his Salisbury posting limited in scope. He felt he was being wasted as the chief of nothing more than a trials unit, and he thought it illogical that he should not have overall control of the R&D effort at Salisbury, including that of the new Australian laboratories. He mistrusted Butement, whom he considered unreliable, and he had no time for the Secretary of the Board of Administration, Eric Cook, whom he thought made his personal ambitions far too obvious.[6] By 1952 Pritchard was fed up with trying to be servant to two masters. His term of duty was nearly up and he wanted to get back home, although on request he did delay his passage until April 1953, just before Bareford's arrival.

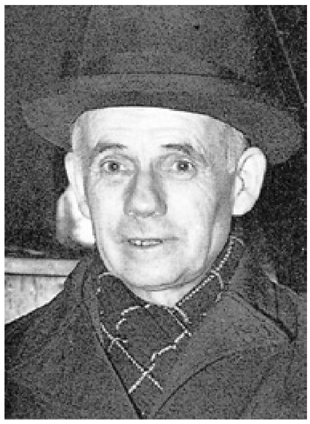
In July 1952 Butement, to Pritchard's disgust, started to push the idea of a 'Central Services Unit' at Salisbury. Under this scheme the many departments of LRWE which were providing services to the laboratories—accounting, stores, hostels and canteens, transport, the registry, etc—were to be taken out of LRWE and rearranged into a central body servicing all four Salisbury facilities. This was to be done in the name of efficiency, although as with the final amalgamation of 1955 political considerations were not far below the surface.



Ivor Bowen.

When he learnt of this scheme Ivor Bowen, the head of UKMOSS and a rather combative man very different in style to his predecessor Evetts, took it as a throwing down of the gauntlet to London. Nor did he hesitate to tell the Board of Management how he felt. In response, Secretary Cook told him forcefully that London should no more expect to be consulted about Salisbury than it would expect to consult Melbourne before altering the organisation of the Royal Aircraft Establishment. Giving as good as he got, Bowen retorted that 'Mr Cook has shown on more than one occasion a tendency to clothe the joint project in an all-Australian wrap'.

Reporting this exchange back to his chief, Sir Harry Garner, Chief Scientist to MoS, Bowen concluded that the excellent and elaborate structure set up in Australia was about to be disrupted and Britain's guided weapons program to be retarded for one dubious advantage: that of giving a more impartial service to laboratories whose contribution to Commonwealth defence would be negligible for years to come. It was an illogical and dangerous step, he thought, arising 'from the acute consciousness held by the Department of Supply at every level from the Secretary downwards that the organisation and staffing of the LRWE is a purely Australian domestic affair'.[7]



Sir Harry Garner. (Topham)

But Bowen's rather lurid interpretation did not find too much favour at MoS headquarters, where the mood was more temperate and conciliatory. Sir Harry himself obviously thought that Antipodean ambitions in the defence research field were unrealistic and pretentious but, as he said, 'however much we may dislike or disagree with this concept, it is no concern of ours and the Australians are determined to pursue it. The best we can do is to see that it does not wreck the LRWE organisation and its capacity to do work for us.' MoS could live with the Central Unit idea if it were introduced slowly.[8] Steuart Mitchell, Controller of Guided Weapons and Electronics, agreed that the Australians should be propitiated to any extent necessary. Getting the GW development program underway was the first and only objective. As he put it with splendid disdain, 'we cannot allow its successful outcome to be jeopardised by trifles—still less by the whim of an Australian official'.[9]

The idea of a Central Services Unit vanished soon afterwards. Why, it is hard to say. Both Bowen and Pritchard were soon to depart, so perhaps Butement decided to delay until a more amenable Australian appointee was squarely in the saddle at Salisbury. If so, he miscalculated badly. He freely confessed afterwards that the selection of Dr Bareford was the worst blunder he ever made.

With these lively events as prologue the 1955 amalgamation could hardly have surprised the officials of the Ministry of Supply, although that did not stop them being unhappy about it. WRE certainly continued to host a large detachment from UKMOSS, but this was hardly the same thing. The amalgamation did signify a real diminution in British control over the daily management of project work. MoS saw that the program of guided weapons research work would no longer be directly coordinated under the project but henceforward would fall under domestic Australian control. It also saw very well that the former Chief Superintendent's grasp over the course of that work had been deliberately weakened. The changes may have sown the first seeds of doubt in London about the practicality of building up a large research effort in guided weapons in another country. On the other hand, MoS could not hope to keep the project squarely under its thumb, not when Australia was quickly acquiring an expertise in planning, conducting and instrumenting trials that rivalled its partner's. It did not take long for MoS to accept the push towards greater self-sufficiency. Of course it had little choice but to do so, and yet it did make a conscious effort to stimulate the kind of development work that might be handled jointly. MoS had all its establishments review their guided weapons programs and draw up a list of those which might be handled at WRE, either entirely or partially. Some of the items on the list did prosper to the point of actually coming into service. For example, the British Army wanted an anti-tank weapon and under the name Malkara it was entirely developed and produced in Australia, WRE's contribution being the development of the motor and the trials at Woomera.

The Australians were by no means unaware of their partner's reaction to what they were doing, but they were firm about its necessity. Howard Beale, as Minister for Supply, alluded to this aspect directly in publicly announcing the amalgamation:

> No doubt our British partners in the joint project would have preferred LRWE to continue as a separate and distinct self-contained establishment. However, Australia has a wider and different interest, because it must take into consideration the work involved in handling our own initiated defence science, which, in the view of the Defence Committee, the Minister for Defence, and myself must maintain its independence and not be subordinated to the joint project. If manpower and economy were ignored, it would be, of course, preferable to continue these as completely independent establishments, but that would result in considerable duplication in buildings, plant, and manpower.[10]

Beale, we see, stressed the economic side of the question which probably was the paramount one. His advisers did not leave it there. With a growing sense of appreciation for the scale of the operations planned by Britain, they were soon pressing for an alteration to the cost-sharing arrangements.

FOOTING THE BILL 2: THE ERROLL AGREEMENT

The situation by the end of 1955 was that the Australian Cabinet was no longer satisfied with the 'indigenous principle' enunciated in the Dalton formula and retained with only slight changes in the Sandys Agreement. The circumstances were no longer those of 1946. Then the country had been making no other significant financial contributions to imperial defence; but the intervening years had brought the Korean war, SEATO and ANZAM responsibilities. Funds for both the joint project and the services came out of the one Defence vote, and hence there was continual pressure from the services to reduce the former's share. The Australian approach to the new negotiations was to call for a change in the sharing formula and to seek a fixed ceiling on its contribution.

In November 1955, as part of a consideration of the defence estimates, the Cabinet instructed Supply Minister Beale to review the Sandys Agreement. He did so, and on 8 December gave Britain formal notice that the Commonwealth wished to renegotiate the terms under which it was contributing to the joint project.

Australia had good reasons for finding inadequate the Sandys Agreement, which was now of slightly more than two years' standing. The British had let it be known that their plans for Woomera were maturing, and had now become far more ambitious than hitherto. On 4 October the British High Commissioner had conveyed the news from MoS that Britain's independent deterrent system, based on the ballistic missile Blue Streak, was pushing ahead at top speed. Australia was going to be asked to build the elaborate testing facilities for it under the joint project. London intended to send out the Minister of Supply, Reginald

Maudling, in November or December, to discuss requirements. But in November, before that meeting could take place (for it had been postponed), another request came asking Australia to begin providing at once the Range facilities for the rocket, Black Knight, then described as 'a preliminary test vehicle for the main weapon'. Nor did the British deterrent weapons program stop at Blue Streak and Black Knight. There was also Blue Steel, the air-to-surface cruise missile with a range of 300 kilometres and a thermonuclear warhead. Blue Steel, whose kerosene/HTP-burning engine drove it down to its target at more than twice the speed of sound, used an inertial navigation system and, in order to perfect it, trials using some thirty models on a scale of two-fifths were planned for Woomera in barely a year's time. For this alone the extra facilities at Salisbury were costed at £300 000 to £700 000. Blue Steel also was urgent, because it was expected to be in service by 1960. The British wanted an air-launched standoff bomb to penetrate the efficient anti-aircraft guided weapons then becoming available in the Soviet Union, and the idea was that Blue Steel would prolong the effective life of the V-bomber force until Blue Streak was perfected. On top of that there were also the nuclear bomb trials. As already described, these used ballistic dummies—including ones for Yellow Sun, the first hydrogen bomb to enter the RAF's inventory.

For none of these trials had any provision been made in the 1955-56 estimates, yet they involved the expenditure of millions of pounds in Australia at an ever increasing rate up to 1960 and beyond. Blue Streak alone would require about a million pounds to be spent on telephone and data communications between Woomera and its impact zone on the other side of the continent. About fifty extra engineers would have to be hired, and another fifty technicians and tradesmen. For all these costs Australia would, under the Sandys Agreement, be solely responsible.

With these ballooning costs in prospect it is not surprising that the Defence Committee reverted to the idea of putting a ceiling on Australia's contribution: a maximum sum payable each year above which every further expense, whether deriving from already approved or yet-to-be-approved projects, would be borne by Britain. The Committee recommended that this ceiling should be £7.5 million. Beale estimated that the yearly expenditure on the project in Australia would be £9.5 million in 1955-56, and peak at £13.25 million in 1958-59. (He was right about the 1955-56 figure, but he under-estimated the peak figure, which reached £18.9 million in 1959-60—the highest annual expenditure during the project.)

Beale endorsed this suggestion and recommended to Cabinet that 'the basis of the renegotiation with the UK Government when Mr Maudling visits Australia should be that of a straightforward ceiling—the amount of such a ceiling to be determined by Cabinet'.[11]

The British approached the meeting with two clear objectives in mind. The first was to persuade the Australians to maintain their contribution at its current level, which was a fraction over £9.5 million a year. The second was to secure a sharing arrangement which was equitable enough to encourage both sides to be economical. They came up with a rather complicated formula whereby Australia should pay the first £10.5 million of the costs in Australia with Britain paying the next two million pounds Australian. The expenses above £12.5 million would be split equally. In addition, Britain would relieve Australia of the current arrangement to pay for half of the Range equipment supplied from Britain. The main concession to Australia in this deal was that it would in practice offer a fixed contribution for four years at least (if the estimates were accurate) while containing a sharing principle if costs rose suddenly and unexpectedly. The original intention was that the delegation to negotiate the new terms should be led by Reginald Maudling, the Minister of Supply; but for various reasons Frederick Erroll, the Parliamentary Secretary to MoS and therefore another politician, was eventually chosen to lead the party on its difficult assignment.

Frederick Erroll, who signed the 'Erroll Agreement'. (Hulton)

Erroll arrived in Canberra in May 1956. Having put the complex proposals to Menzies and the Ministers representing the Treasury, Defence and Supply, he quickly discovered that they had a much simpler counterproposal: what they wanted was to fix a ceiling to their contribution of £9.5 million a year. Here the bargaining began. Erroll argued strongly for some retention of the principle of sharing, arguing that Australia's share would in practice be limited for quite a few years. At this point the meeting adjourned. The Australians put their heads together and then Menzies called Erroll in. He pointed out that the clause in the Agreement would still stand that either party could order a review if costs rose suddenly, so it was unnecessary to have a specific limit. To have a threshold of £12.5 million before sharing began was to his mind altogether too lavish: there would not be enough incentive for economies below that figure. Finally, the history of the previous few years had been one of constant pressure on the Australians to get work completed at short notice. This meant a good deal of overtime, which in future he thought should fall to Britain to pay. Taking all these things into account, the offer he was making now was a fixed maximum sum of £9.5 million a year. When Erroll transmitted this offer back to London it was accepted.

The signing of the Erroll Agreement only modified the Dalton Formula to a limited degree, but it did begin the process of shifting the financial load on to British shoulders which became still more marked with the succeeding Thorneycroft Agreement. Menzies had struck an excellent bargain for his country, though privately many raised their eyebrows at Britain's recklessness in signing such an agreement. What need was there now for its partner to restrain the spending, as there had been under the Dalton Formula? Whether there is any truth in the whispers about Australian profligacy after this date it is impossible to say. But it is a fact that the 1960s and 1970s saw many a year when Britain was paying just as much into joint project work at Salisbury and Woomera as the Australians were; indeed, there were a few years towards the end when it was paying more.

AN OVERVIEW OF THE ESTABLISHMENT IN 1965

The amalgamation of 1955 fixed the essential shape of WRE for thirteen busy years. There were many changes of name and some redistributions of responsibility over this long period, but none of them were of external or permanent significance. In order to give the reader an overview, therefore, the manifold activities of WRE will be described as they were in 1965, at the end of the 'Boswell years'. By this date the work being done under the joint project had reached or perhaps had just passed its point of maximum expansion.

In 1965, then, all the technical work at Salisbury was handled by one or more of four large wings.

Trials Wing planned, conducted and assessed all the trials at Woomera, and planned the development and further instrumentation of the Range to meet the requirements of the joint project as its needs evolved. It was divided into two divisions. Trials Division did the trials and then processed the maze of data with digital computers of ever growing complexity. In 1956 the Elliott Bros computer, WREDAC, was installed, together with data conversion equipment designed and built by WRE's engineers, but such was the rate of increase in trials that three years later it was thoroughly overloaded. In 1961 an IBM 7090 was put in service, one of the new generation of transistorised machines. Another division, Instrumentation Systems, devised and provided most of the optical and electronic instruments required to test the guided weaponry.

Space Physics Wing was divided into three divisions. One of these, American Projects, had little to do with the joint project. It helped to install and operate US tracking and data acquisition systems in Australia. Another division, Systems Assessment, was concerned mostly with the mathematical modelling of guided weapons using digital and analogue computers. It maintained and developed much of the analogue type computer equipment at Salisbury. The third division, Applied Physics, was a research facility examining the phenomena associated with the passage of bodies through the upper atmosphere. Such work had both a military and a purely scientific side to it. The division helped to develop suitable rockets and the experimental packages which they carried to the fringes of the atmosphere.

Weapons Research and Development Wing worked primarily on Australian defence projects, although it supplied services when required to the joint project. Of its three divisions, Aerodynamics investigated the behaviour of flying models, both in supersonic wind tunnels and in free flight using rocket boosters. Chemistry and Physics researched rocket motor propellants, vacuum and electronic physics, the behaviour of materials at high temperatures, and telecommunications. Weapons Projects devised specific weapons systems and their guidance and propulsion techniques. Its activities revolved around Ikara, the all-Australian anti-submarine guided weapon, for which it developed the guidance and propulsion systems.

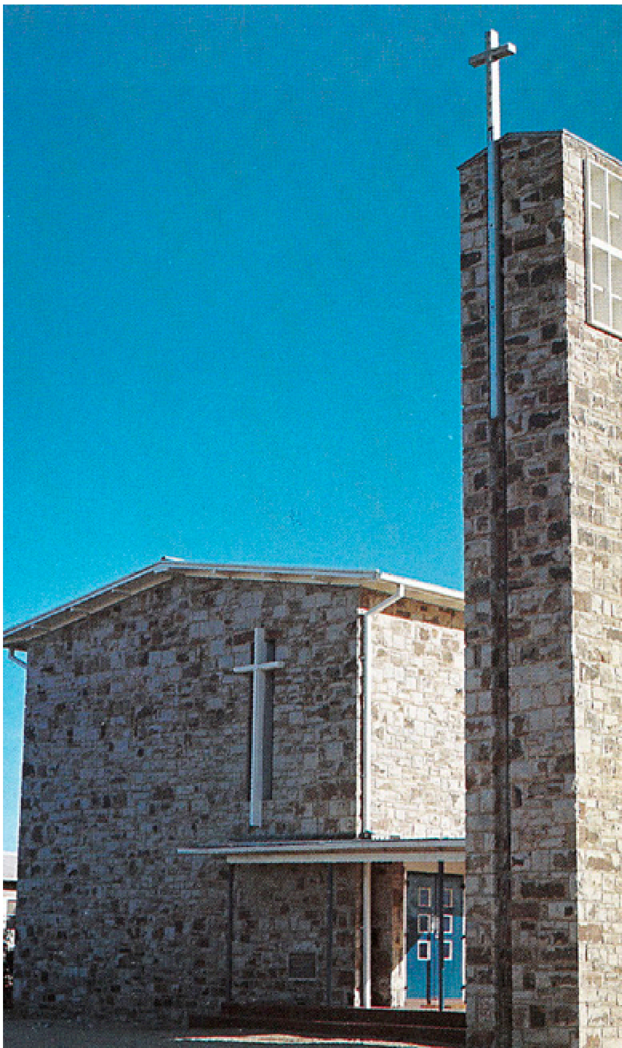
Engineering Wing was the factotum of the Establishment, for which it undertook all manner of construction and manufacturing work. One or other of its three divisions (Design and Workshops, Facilities and Electronics and Communications) built most of the equipment, instruments and plant used at Salisbury and Woomera; planned and estimated for all new construction work in conjunction with the Department of Works; liaised with the

▲ Nearby mulga country, normally dry and dusty, carpeted briefly with wildflowers after a rainy spell. (Jim Frost)

▲ Insert: A flower head of Sturt Pea (*Clianthus formosus*) south of Lake Hart, after rains. (Jim Frost)

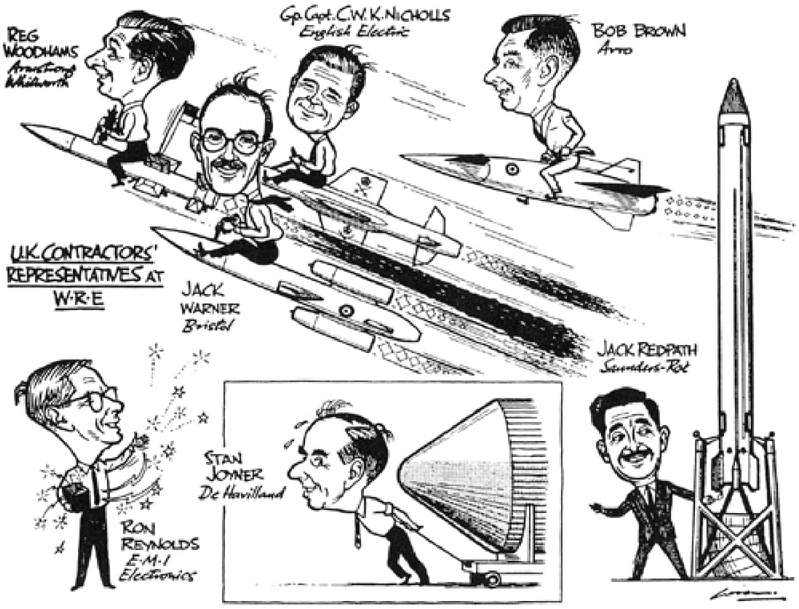
▼ The long dusty road to Port Augusta, now sealed. (Jim Frost)

▼ The United Protestant Church. (Jim Frost)



An Adour radar, still in use at Range E.

One of the long-range tracking cameras used at Woomera.



'UK Contractors' representatives at WRE'—sketches by Wren for *Aeroplane and Astronautics*, 11 March 1960. (*Flight* magazine and Mrs E. A. Wren)

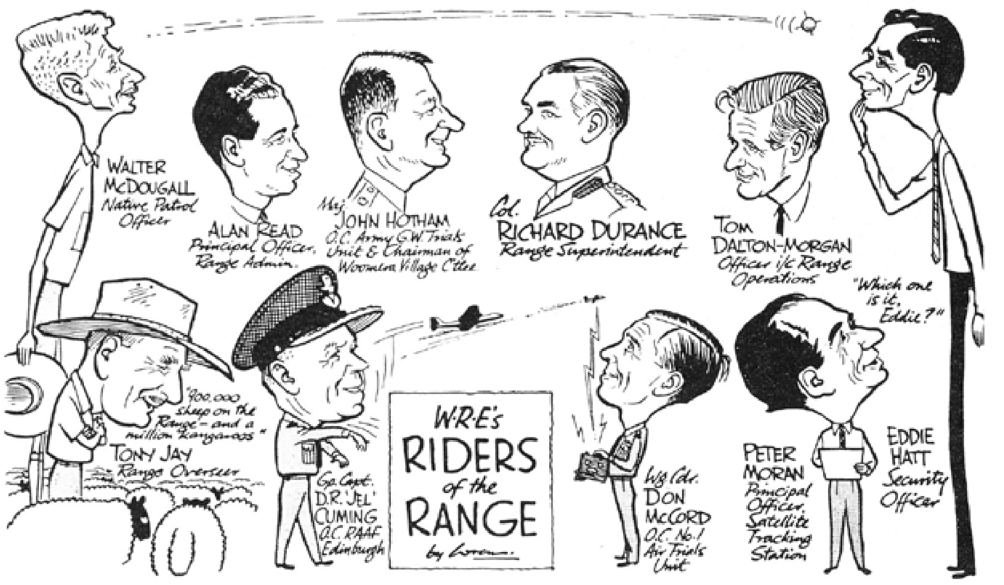
PMG over communication and data links; operated the library; edited and published all the literature put out by WRE, and tackled an endless stream of other jobs.

Weaving all this effort together and infiltrating every part of it was the Administration Wing. It administered Woomera; looked after finance and the supply of goods; ran the clerical and typing services, the cafeterias and the file registries; recruited personnel, staffed the telephone and the teletype machines and even did the gardening.

There were other entities linked to WRE on the Salisbury site in 1965. It has already been mentioned how the British presence in Australia was maintained by a detachment of Ministry staff, called BDRSS, the British Defence Research and Supply Staff. (It had passed through several intermediate titles, originally being UKMOSS(A).) Its headquarters were in Melbourne, but it was represented at Salisbury by a small group of officers who naturally worked closely with WRE and were responsible for the financial and technical progress of each project and, in some cases, the overseeing of local MoS contractors. By 1965 BDRSS at Salisbury was close to its staffing peak with a Head of Staff in charge of a team of twenty-five or more, including some local recruits.

In general each project had its own BDRSS staff officer at Salisbury to manage its affairs on behalf of MoS. In the case of the guided weapons, this officer was normally a member of the armed services concerned, while scientists and engineers from British research establishments handled the space projects. Other officers gave technical support over such matters as Range instrumentation or target aircraft, and each of the British quality assurance branches had its representative. A small administration section dealt with WRE on joint project policy and finances, provided office services and looked after the domestic and welfare needs of the group and the continual flow of British visitors. Up to ten of the staff were recruited locally and formed a permanent nucleus in BDRSS, helping the new arrivals and providing a welcome continuity in the office routine. The rest of the staff were on fixed spells of duty, usually for three years, but quite often the experience was so popular that extensions were arranged, if not contrived. The UK government owned a number of houses which were maintained by BDRSS for its staff, and being mostly scattered around the Adelaide suburbs these gave the families Australian neighbours. There were plenty of social activities: camping trips, a Christmas nativity play for the children and an annual cricket match between BDRSS and WRE staff.

Rapid communications between BDRSS and London were maintained by the secure Defence Teleprinter Network which had terminals in the BDRSS building. It was constantly in use, especially during trials periods. The usual terse form of teleprinter message could produce misunderstandings of feelings and intent, and informally styled messages were the rule; but occasionally people used 'telegraphese' to good effect. One officer, exasperated by the delayed reply to his request for data, sent an urgent message to RAE: 'cannot do analogue computation until you have done digital extraction'. The teleprinter could not handle the transmission of trials results, so in 1965 great quantities of printed tabulations were being



'WRE's riders of the range'. Some Woomera identities as sketched by Wren. (*Flight* magazine and Mrs E. A. Wren)

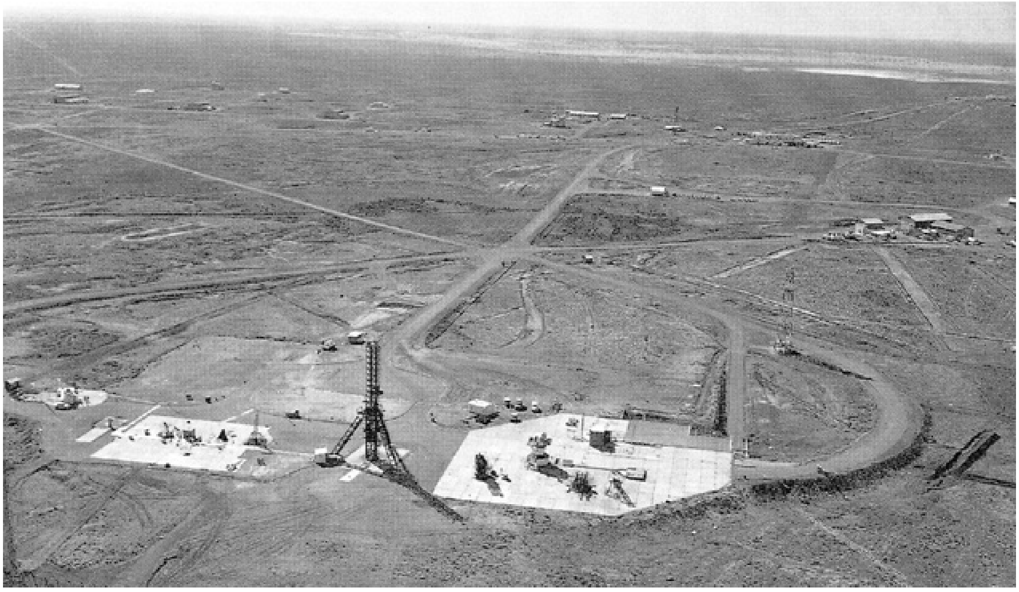
sorted, catalogued and physically dispatched on the charter flight. By 1972 a high-speed data link between the two countries was in operation, transmitting the information directly in digital form.

The closure of the Black Arrow project in 1971 marked the beginning of a long run-down of BDRSS. The last Head of Staff returned home in August 1974. Several of the local staff became redundant about this time, some to be re-employed by WRE. BDRSS contracted further with the completion of the Sea Dart trials in 1976, and in 1978 the few remaining personnel of BDRSS Salisbury were disbanded. A small residual organisation in Canberra survived the end of the project.

Another important technical presence at Salisbury were the contractors. Many British electronics and aeronautics firms had been given contracts to develop weapons or their components, and many of them found it worthwhile to set up Australian subsidiaries or branches adjacent to WRE on the Salisbury site, forming a miniature 'military-industrial complex' the like of which had never been seen in Australia before. They were invited and encouraged to do so by MoS, in line with the guiding philosophy which stood behind the project in its first years—namely, to transfer much of Britain's guided weapons R&D work to Australia. At Salisbury that part of the factory on its northern side which had formerly been devoted to shell filling was allocated as the Contractors' Area, and each company set up its headquarters there. The nucleus of a company was generally made up of six or eight people brought from Britain, who then recruited local engineers to make up a workable trials team. At the height of activity the contractors included the British Aircraft Corporation, Hawker de Havilland, EMI Electronics, Fairey, Ferranti, GEC, Hunting Engineering, Rolls-Royce, Sperry Rand and Westland Aircraft.

For some years the contractors' role was a fairly humble one. They received the weaponry and test vehicles complete from the British factory, prepared and fired them at Woomera, then sent the raw data back for analysis. Gradually, as their tasks for the joint project changed and evolved, the contractors took on a more responsible role and started to manufacture and modify equipment in their own right, sometimes winning Australian Defence Department contracts. Though still controlled from Britain the Australian branches started to lead a more autonomous existence, becoming registered companies in South Australia.

After 1953 the contractors' interests were protected by an association. Towards the end of that year Colonel Elvish of Fairey proposed to the four other firms then at Salisbury (Bristol Aeroplane, EMI, Vickers-Armstrong and English Electric) that they should present a common front in negotiating with government departments on matters of general interest and as a means of fostering goodwill between the departments—especially Supply—and the firms. This organisation was first named the Guided Weapons Contractors' Committee and later the Association of Defence Contractors. At the peak of trials activity at Woomera it had fourteen member companies, but eventually it represented only the four major survivors at Salisbury. Its functions finally became those of arranging consortia to handle



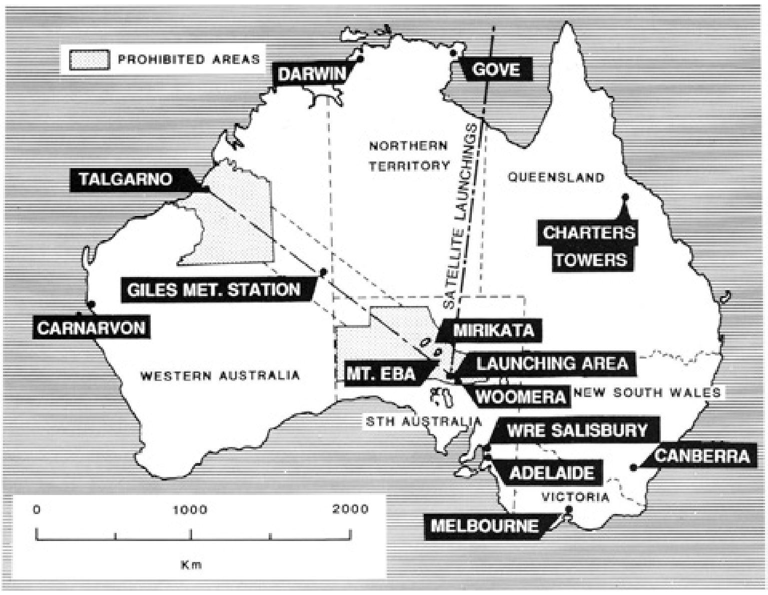
Launcher aprons 1 (right of the prominent Skylark launcher) and 2 at the Range E rangehead. Behind these are the test shops and instrumentation building and in the distance a dry Lake Koolymilka.

large projects, cooperating with overseas companies, and exchanging information between its members on the many techniques required in the fabrication and testing of modern military equipment.

So much for Salisbury. By 1965 Woomera too was a substantial and bustling town, home to more than five thousand people. From the domesticity of the village one drove out to the ranges, passing on the way the Tech Area consisting of a modern administrative centre and a cluster of other buildings: a project hangar, powerhouse, workshops, stores, canteen, bulk fuel depot, and a place to determine the centre of gravity of vehicles.

At the rangehead (which strictly speaking was the head of Range E, the main range) the biggest structure was the Instrumentation Building, housing the main control, communications and recording equipment for trials. In front of it were the launching aprons with some fixed launchers and, to the side, the heavily armoured blockhouses of the equipment centres. These housed the monitoring apparatus and power and air supplies. Below ground were the test posts, where the last-minute checks of the missiles out on their launchers could be carried out safely. Behind the instrumentation building lay the test shops where the missiles were prepared after arriving from Salisbury or overseas, and various common facilities: a measurements shop, a liquid fuel and oxidant filling post and a magazine area for storing boosts and explosives. Close by, on the margin of a normally dry lake, was the little community of Koolymilka with its pool and messes. 'Kooly' was a local base for some of the essential services that needed to be at hand: transport, fire-fighting, Commonwealth Police, and the Department of Works. Visitors sometimes stayed there, and the Range staff used the large canteen for lunch.

At the rangehead and spread out along the flanks of the Range were the many instruments which were its senses: kinetheodolites, launcher cameras, telescopic high speed tracking cameras, doppler systems for ascertaining speed, tracking and surveillance radar and their plotting tables, various items connected with telemetry such as aerials and receivers, a missile tracking system with its computer and plotting tables, and two central timing units to lock the whole network into a precisely known, common time. The facilities at Range E were by no means all there was to the Range in its heyday. Elsewhere there were several subsidiary launching sites, including Launcher 5, a few kilometres from the rangehead, where Black Knight and Black Arrow were prepared over many years, and the sprawling Launcher 6 site at Lake Hart. By the early 1960s there were two big and largely self-contained instrumentation posts at Mirikata (185 kilometres down-range) and at Red Lake (40 kilometres from Woomera), as well as extra ballistic camera posts at distant locations. For some years WRE maintained a tracking station on the far distant northern edge of the continent at Gove in Arnhem Land; and it also ran in conjunction with the Meteorological Branch the weather station at Giles, far down-range in the Aboriginal reserves. At different times WRE had a presence at Talgarno, near the north-west Australian coast and a telemetry station in northern Queensland. At its peak, then, Woomera Range virtually encompassed the whole continent. Here were tested a whole armoury of guided weapons under the joint



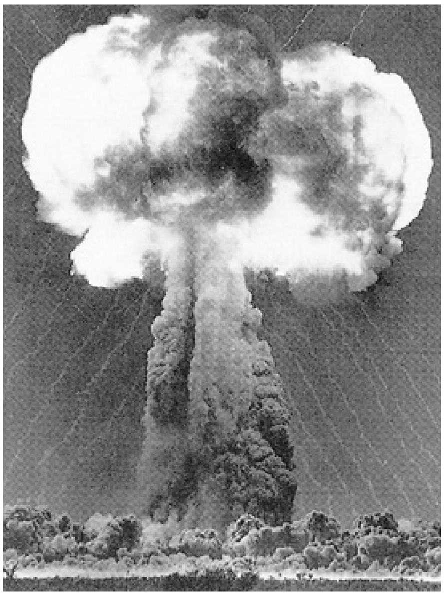
The main Australian centres associated with the Woomera Range at its peak.

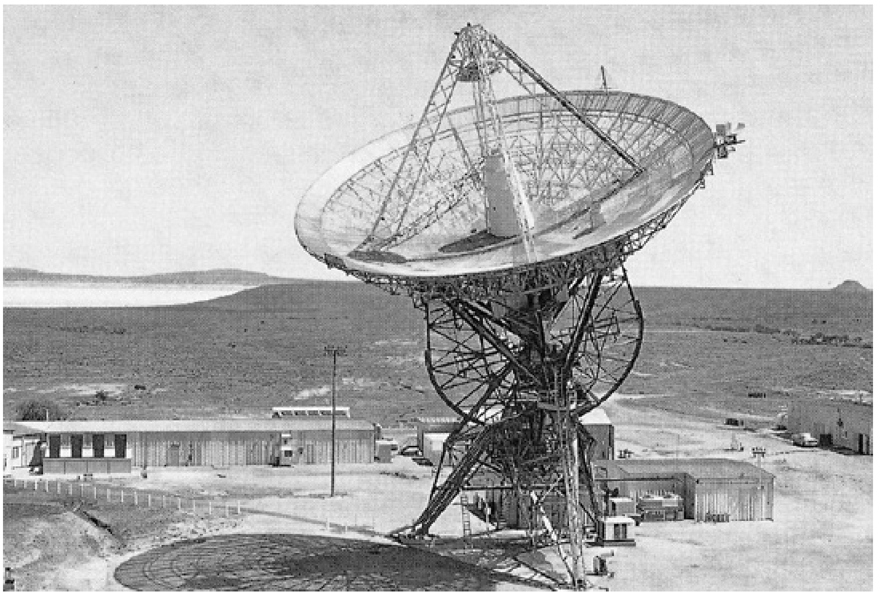
project: familiar names like the air-to-air Firestreak and Fireflash; the air-to-ground Blue Steel; and the ground-to-air Seaslug, Thunderbird and Bloodhound. Here the partners, sometimes in conjunction with others, made tentative essays into space with projects which blended military with purely scientific research: the warhead testing programs, Black Knight and Sparta; the satellite launchers, Black Arrow, Redstone/WRESAT and Europa; the upper atmosphere research rockets, Skylark, Long Tom, HAD, HAT, Falstaff and others. Here too the pilotless target plane, Jindivik, was perfected and flown on hundreds of sorties from the adjacent Evetts Field.

Nearly 500 kilometres down the centre line of the Range and slightly west of it lay Emu Field, a claypan where areas of fused sand and slag marked the sites of the two British atomic tests of the Totem series conducted there in October 1953. About 177 kilometres south-south-west of Emu, much closer to the transcontinental railway line at Watson and in a separate prohibited area, was Maralinga, a more substantial memorial to joint atomic weapons testing. Maralinga village was a ghost town but still intact in 1965, for work at the testing ground nearby had finally come to a halt only two years previously. At Maralinga between September 1956 and October 1957 had been exploded the atomic bombs of the Buffalo and Antler series. After the bomb trials had ended with Antler, further 'minor' trials under the Experimental Program had continued almost without pause until 1963. Of these trials the Vixen A and B series had investigated the effect of accidental fire or chemical explosion on nuclear weapons, and their effect had been to release plutonium into the environment, especially around the site named Taranaki. Operation Hercules, completed in November of the year before, had been one attempt to clean up—another would follow in 1967—but in 1965 more than 20 kilograms of plutonium was present at Maralinga, either entombed there or ploughed into the top layers of the soil.[12]

The atomic tests were not conducted under the joint project but under a separate agreement. The distinction, particularly before the foundation of Maralinga permanent test range, was in practice a hazy one. Working time then was not so closely accounted for as it was later, so much unrecorded joint project effort flowed into the tests, including the use of some facilities and staff at Woomera and Salisbury. The workers from Emu went regularly to Woomera for their rest and recreation, and heavy use was made of LRWE's Bristol freighters to transport stores to Emu. LRWE engineers developed the radio and line services to the testing sites. Canberra and Lincoln bombers were decontaminated at Woomera after the Totem firings, peace officers were seconded from Woomera and, as we have seen, the Native Patrol Officers were involved in the trials and their aftermath as part of their typical duties.

Finally, although they had nothing to do with the joint project and only involved WRE to a limited extent, mention should be made of the American space tracking stations in Australia. The first such station came in the International Geo-physical Year (1957), with the satellite tracking Minitrack system at Woomera. Later stations were established at Island Lagoon near Woomera; at Muchea and Carnarvon in Western Australia, at Cooby Creek in Queensland, and Tidbinbilla, Orroral Valley and Honeysuckle Creek in the Australian Capital





Territory. The stations were operated and maintained by Australian staff, and the station directors and some assistants were usually WRE officers. They helped to sustain the public's perception of Woomera as an exciting place, of which almost anything might be expected.[13]

Above left: The mushroom cloud from the third British atomic bomb explosion at Maralinga (November 1957).

Above: The NASA deep space station at Island Lagoon.

FOOTING THE BILL 3: THE THORNEYCROFT AGREEMENT

By 1965, the date of the overview just given, the Erroll Agreement had given way to the Thorneycroft Agreement of 1962. The new agreement had arisen directly out of the cancellation of Blue Streak in 1960, a story told in Chapter 22. The records of the negotiations which followed the expiry of the Erroll Agreement give the sense that this was a period of some bitterness when the previously equable atmosphere was dissipated for a time. Matters were now to be put on a more business-like footing. At long meetings long lists were prepared and presented of services which previously had been provided free, but which both sides now insisted must be shared.

How did matters look now from the British side of the negotiating table? The inescapable fact was that the need for guided weapons trials at Woomera, while still heavy, would be falling off substantially over the next few years to the point where by 1970 Woomera would be simply underused, unless the ELDO satellite launcher project expanded to take up the slack. At all costs, therefore, the British were determined to seek an arrangement whereby the country was not irrevocably tied to a heavy, fixed, annual contribution to the project for comparatively little usage. On the other hand, Woomera had to be maintained, for keeping the facilities for some weapons testing was crucial to British defence plans. The only lasting solution was to find some other customers for the Range. The Australians concurred with this diagnosis and together the partners put in a good deal of effort trying to sell its services in the United States, Europe and Japan. They had little success.

The main points in the negotiations were first that the new agreement should be for a lengthy period—a minimum of five years. Second, that funds for Australia's own defence R&D work (which was growing rapidly at that time) should be clearly separated from its contribution to the joint project. Britain also insisted that certain small receipts from project work should be credited direct to the project and not to the Australian Treasury; it also insisted that the project be billed for certain expenses which it had been meeting from other sources. The total here saved Britain about half a million pounds Australian a year. For its part Australia wanted about one million pounds Australian added to the account of the project. These various claims were the result of a careful bookkeeping exercise on both sides.

Under the final terms of the Thorneycroft Agreement of 1 July 1962 (named after the British Defence Secretary of the time) the last vestiges of the Dalton Formula, of the costs lying where they fell, were abandoned. So was the Erroll Agreement ceiling of £9.5 million below which all costs were paid by Australia. Now, *all* the joint project costs incurred in

Australia were divided in the proportion of 54.4 per cent to Australia and 45.6 per cent to Britain up to a ceiling of £8.7 million a year, above which Britain paid the balance. Splitting costs below a lowered ceiling meant, of course, that Britain's share of the total costs was greater than ever before. On the other hand both partners now had an interest in scrutinising all the costs from the bottom up. Once the ELDO program started to build up between 1960 and 1962 morale much improved on both sides, but the financial arrangements had to be much more complicated with the participation of several other European countries. The era of free, even lavish spending which had marked the last years of the 1950s was now over and both sides were much more careful than they had been in monitoring their expenditure. The hallmark of the Thorneycroft Agreement, therefore, was a much more precise and defined accounting procedure.

The Thorneycroft Agreement ran its full course up to July 1967. The Australians wanted to extend it for another five years, but their partner declined to commit itself to such a long period without reviewing its needs. By that date it was plain to all that the time of growth was over.

Notes and Sources

1. The following account of Dr Bareford's career at LRWE/WRE is largely based on the reminiscences of Dr H. J. Brown and Emlyn Jones at interviews of 9 July and 25 July 1985. Bareford died in January 1980.
2. Letter dated 17 May 1955 from Minister for Supply to Prime Minister. AA A816 3/302 98.
3. Reminiscence of Peter Twiss at an interview of 31 January 1985.
4. Jones interview. Both Jones and his wife recall this incident vividly.
5. Aide-memoire dated 24 January 1951 from the Office of the UK High Commissioner.
6. Pritchard conveyed these impressions to the new Head of UKMOSS, Ivor Bowen, who passed them to the Ministry of Supply's Chief Scientist, Sir Harry Garner, in a letter dated 14 July 1952. PRO file AVIA 54/1905 74825.
7. The two quotations are from a letter dated 8 July 1952 from Head of UKMOSS Ivor Bowen to Chief Scientist MoS Sir Harry Garner. PRO file AVIA 54/1905 74825.
8. Untitled notes on 'the Australian situation' attached to a letter dated 18 July 1952 from Sir Harry Garner to Controller GWE S. S. C. Mitchell. PRO file AVIA 54/1905 74825.
9. Letter dated 10 September 1952 from S. S. C. Mitchell to Ivor Bowen. PRO file AVIA 54/1905 74825.
10. Letter dated 30 March 1955 to Defence Minister McBride. AA A816 Item 3/302198.
11. Proposal dated 19 March 1956 for the Revised Formula 1956.
12. For further information on the Emu and Maralinga sites and their relation to the joint project see J. L. Symonds' authoritative *A History of British Atomic Tests in Australia*. AGPS, Canberra, 1985. A much more readable but still accurate account is Robert Milliken's, *No Conceivable injury: the story of Britain and Australia's atomic cover-up*, Penguin Books, Ringwood, 1986.
13. For the first two years or so the early Minitrack and Baker-Nunn camera facilities at Range G were operated under joint project auspices. After that the tracking stations became a joint US-Australian project.

13 At home in Woomera

LIVING IN A DESERT TOWN

Many aerial photographs exist of Woomera in its various stages of development, and a glance at one of those taken towards the close of its second decade at once presses home the painfully contingent appearance of the town. Most human settlements, when they are viewed from the air, readily reveal why their site was chosen. They cluster round a ford or an important crossroad, or else rim a good harbour; they are dominated by cones of mining spoil, huddle for safety against a cliff face or straggle at ease along the bottom of a fertile valley.

But Woomera is different. From the air its purpose is quite opaque to the naive eye. Stuck on a stony plateau as though with 'an inferior brand of glue'[1], where the sole sign of human activity is the random scribble of vehicle tracks, the only clear impression is that whatever purpose brought it to birth must have been an imperative one indeed. Like some sweetmeat coloured rust and olive, the village is a tiny portion of blank plain scored into neat rectangles. Some of the blocks are just fenced sections of desert, and the houses on them look like models dropped into a child's sandbox. Others now support so much rampant plant life that only the roofline is visible. A low level view also shows the brave public plantings of trees along the ruled lines or symmetrical curves of the streets. Each tree casts a tiny shadow on the bare ground and each one stands in the centre of a dark

A vertical aerial view of Woomera in 1962.

A low level aerial view in 1962. In the foreground is St Barbara's Anglican Church and behind it the United Protestant Church.

damp patch of fertilising sewage effluent. Impossible to forget that the vegetation is no less a stranger here than the houses. Woomera is a splash of green in the desert, but it is no natural oasis. All bespeaks the triumph of artifice over niggard nature in this region. The site on which it sits is naturally treeless and shrubless; indeed, apart from a sparse covering of scrub, it was originally devoid of any vegetation at all. In 1949, when its construction was well under way, the village could boast only one tree more than a metre high. It was a native bluebush transplanted into someone's garden, and even that died with the onset of summer. Its owner was so desperate for the sight of some plant life that he considered spraying it with green paint.

There are reasons other than the sparse rainfall for the infertility of the Arcoona Plateau. It is not merely that the soil is desiccated. As one can see in Arizona or Israel, some desert soils can be very productive when watered and fertilised properly. Unfortunately the soil of Woomera is not of this light and friable kind. Just below a thin surface crust is heavy clay, nearly impenetrable to the roots of plants and impervious to water. Even worse, the clay is loaded with salt. At the coalmining town of Leigh Creek in outback South Australia, where the climate is much the same, the total soluble salts content of the soil is around 0.05 per cent. At Woomera the salt level is anything up to 5 per cent. This spells death to most plants. Only a few species of trees and shrubs will grow at all under these conditions, and then only if they are acclimatised slowly. Seedlings, saplings and vegetables will not grow at all except in raised beds of imported soil. In short, only a masochistic nurseryman would have tried voluntarily to cultivate anything on the plateau where Woomera was rising.

Since there was no choice, however, the architects of Woomera were keen to see what could be done in the formidable circumstances. Both Evetts and the engineer, Wynn-Williams, were convinced that the desert could be made to bloom if only the right techniques were adopted. Evetts interested himself systematically in the business. He left Australia before much of the work bore fruit, but on his last visit to Woomera late in June 1951, when he was accompanied by the horticulturalist, Sir Russell Grimwade, he said that his great interest apart from his technical work had been promoting research at Woomera into plants and grasses which might one day regenerate the Dead Heart and make useful millions of square kilometres of arid territory.

This was too optimistic a vision, but within the confines of the village great things were then being done. The man who was primarily responsible for the greening of Woomera was R. H. Patterson, a senior arboriculturalist with the Commonwealth Department of Works, who later wrote a very interesting account of his experiments.[2] In his first plan of action submitted to the Board of Administration soon after his appointment in April 1948, Patterson recommended that a base nursery should be set up at once at Port Augusta to serve a forward nursery at Woomera itself. Adventurously, Patterson proposed very heavy tree plantings to make a green belt around the village, and to line the residential streets. He intended to use the effluent from the sewage plant on the public plantings, watering them constantly until they were mature enough to look after themselves.

Patterson was a most resourceful man, and barely a year after his first proposals had been accepted he had chosen a hundred varieties of trees and shrubs—a third of them eucalypts—which he thought might prosper under the tough conditions. He had samples growing at Port Augusta, where some of them sprouted 60 centimetres in the first year, double the Adelaide rate. From this base nursery he moved them to Woomera itself, to a site which soon became famous as the Arboretum. In use by the end of 1950 and complete by June 1951, the Arboretum was the only arid-country research nursery in Australia at the time, which suggests how completely Patterson was breaking new ground.

The Arboretum flourished from the start. Patterson soon had experiments underway into such matters as finding what sort of grasses could best be used for lawn. He imported seeds from all over the world for these experiments. In its first couple of years the Arboretum provided 8000 trees to line the residential streets. They were planted out when about half a metre tall and from constant watering with the rich effluent they grew almost visibly. About half a hectare of the green, belt was planted, but it never achieved the dimensions envisaged by Patterson. In fact some 5000 trees in very outlying areas were abandoned after a few years, and apart from a few which happened to be near natural soaks they soon died and were removed.

At the height of its activities in the middle 1960s the Arboretum was one of the most familiar and approved of Woomera's institutions. It was propagating 10 000 seedlings a year in its nursery, using a potent mixture of sewage sludge, peat moss and dune sand. It issued about half of these free to householders in the winter months for their own gardens; the rest went on renewing and extending the plantings in the public areas. It tended the adjacent Breen Park, a luxuriant stretch of greensward shaded by enormous gums, which Director Bill Boswell had founded but with typical modesty would not permit to be named after him. Close on 30 000 trees lined the streets and the approach roads.

Yet for all that the whole creation was artificial, and likely ever to remain so. The trees, shrubs and 4 hectares of lawns required the continuous attention of nineteen men and, despite the best advice from the Arboretum, fewer than half of the plants handed out survived transplantation into private gardens. It was a triumph for hydroponic rather than natural gardening. From the sewage farm north-east of the village, the effluent was pumped through a 6-inch main and reticulated around most of the public areas: the ovals, messes, blocks of flats and so on. The small Woomera West plant supplied enough effluent for a plantation of trees along the Technical Area road. The more distant areas were watered by tanker. Three tankers, each holding 4500 litres of effluent, moved slowly along a fixed round watering each tree separately through a pipe sunk alongside it. The pipe had a lid to reduce evaporation. Each two man crew completed its round in fifteen working days, whereupon the cycle began again. It was an arboricultural version of painting the Forth Bridge, and just as unremitting, for no matter how large the trees grew it never proved possible to wean them off the watering program. When the program was cut back in the name of economy towards the end of the project the trees began to die at once, and their skeletons around the perimeter of the village presented a most dismal sight.

But the triumphs of the Arboretum still lay far ahead for the first bemused families who came to live at Woomera. It was all too clear that fate had cast them in the role of pioneers in a frontier town. Everything was raw, chaotic and barren. Construction materials and debris were piled everywhere in the heat and the dust, and apart from the houses the only buildings were shacks, tents and huts. Very few had the imagination to visualise what Woomera might one day become. One who did was Brigadier E. M. (Tiny) Neylan, a small nuggety man who was Range Superintendent in the difficult period from September 1948 until he retired in May 1951.

Most of the many stories about the 'Brig' centre on his drinking capacity which was remarkable even for the village. For example he boasted loudly that he could identify by taste all the blends in a particular whisky. A friend proved this talent was limited when half-way through a party she secretly substituted a bottle of cold tea for his usual tipple, which he continued to down happily for the rest of the night.[3] Neylan exploited his prowess with the bottle by arranging a sort of initiation ceremony for the new recruit. He would trap him in the mess late at night, amiably fling an arm round his shoulders, and roar for the bar to be reopened. They would drink on to dawn, Neylan encouraging a stream of confidences from

Below: The Woomera Arboretum.

Below left: Checking the pipes sunk alongside all trees for watering (1951).

Brigadier Neylan, the Range Superintendent, plants the first tree in August 1950.

the naive newcomer. At first light it was understood that the latter should reel off heroically to work. Neylan did not follow. Having slept off the ill effects for a few hours, he would turn up shaved and sober in an immaculate uniform and jovially accuse the new chum of having a loose tongue. Neylan's best quality was his approachability. His predecessor, stiff and rank conscious, had behaved as though he felt that consorting with civilians from Salisbury was beneath his dignity. Except on strictly formal occasions Neylan was ready to befriend everyone, and made no secret of his belief that the military were only temporary caretakers. The real future of the Range, he thought, lay in civilian hands, and Woomera was destined to become a real town. When dispirited new staff and their families turned up for an initial briefing, Neylan would leave them incredulous as he expounded in a hoarse, whispery voice his vision of the future township, cheerfully pointing out the sites of schools, shops, hospitals and the other usual urban features; sites which in 1949 were nothing but red dust and gibber stones. Neylan was another of those who supported the Arboretum in its early days, though he knew little about gardening. A friend remembers him scuffing the dust moodily with his boot, muttering, half to himself, I'm sure things ought to grow up here'. He seemed to half expect the seedlings he did plant to spring up like giant beanstalks.

Neylan was not the only one with misconceptions about the place to which fate had brought them. Before they arrived there, even some of the Australians who should have known better entertained very defective notions about the terrain around Woomera. They were seduced by the inviting sweeps of blue on the map and visualised weekend boating and water skiing. Roma Birkill, who at that time lived in Albury, wrote to her husband who had been posted to Woomera, asking him which of the glorious lakes he swam in. 'For some reason he didn't answer that!' she now recalls ruefully.[4] Others cast a more pessimistic eye over the map and assumed they would be fending for themselves; one new arrival turned up with a set of rabbit traps, ready to live off the land. As for the arrivals straight from Britain, often they were reminded of the covers of science fiction novels set on Mars; the same ochre desert, the few meagre plants, the sky an unlikely colour, and the angular shapes of strange devices on the horizon. Most of their friends and relatives back in Britain had only the haziest idea of outback life, and those who passed regularly between the two countries had a good deal of fun at their expense. One De Havilland employee diverted his Welsh relations with tales of building a rocket launcher with a screwdriver and pliers while his mate kept a rifle trained on the marauding natives, who would come charging over the ridge preceded by their kangaroo shock troops.[5]

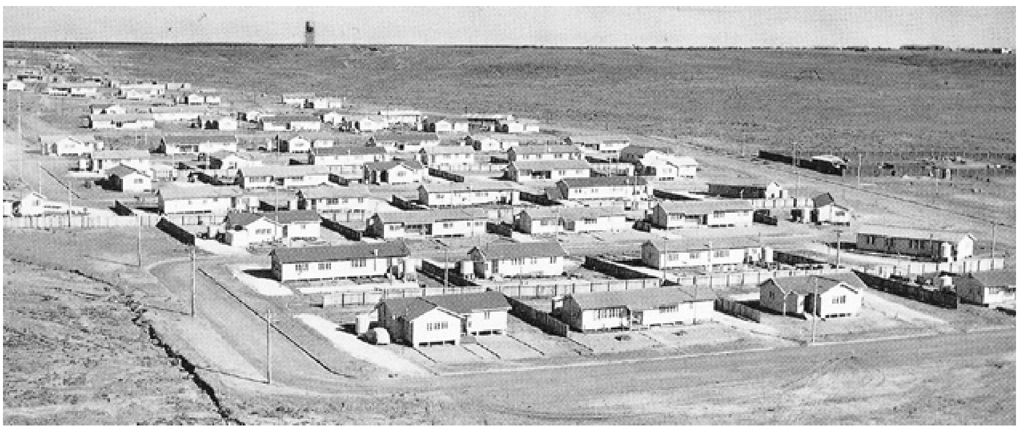
The first few families came to the village early in 1949, with Squadron Leader Len and Dell Smith taking the first house of all. By that October, thirty families with forty young children were settling in and finding their powers of adaptation were sorely tried. Their houses were more or less complete, but they lacked everything except the most basic furniture. Even finding one's house could be a problem. The houses in each area were identical. Few of them had fences or gardens or made footpaths, and they were surrounded by such a featureless expanse of dust, stones or mud that the only recourse was to hang something on the washing line so as to mark out one's own. Nor could one mount a shopping expedition to collect what was needed, for there were no shops in the village; instead there was an organ of the Army called DID (Details Issue Depot). The DID had good stocks of food but it was not geared to handle cash sales. In the first primitive stages the first householder was charged for the whole community's order and had to get the money back from everyone else. Afterwards one ticked off the required items from a list and the groceries were delivered three times a week; if no one was home the DID man would put the milk in the fridge. This arrangement went on for two years until the temporary store opened in February 1951. At one point the DID headquarters mysteriously burnt down destroying all record of the outstanding bills, and in a vague attempt to recoup some of the losses, each family was charged the surprisingly modest sum of £20 for six months' provisions.

Unfortunately the early planning of family accommodation at Woomera left something to be desired. Although it was always part of the plan that a permanent community should live at the Range, notions of how these families should be housed and what facilities they would require to make life tolerable were pretty rudimentary. In the initial specifications, the bulky 'Bible' of 1946, is a map showing what the Range might look like after three years, and it includes a 'residential area' of 200 houses and a hostel for 700 single men. Apart from that, the 'Bible', so expansive about minute details of equipment, is silent on the subject. Designing the ideal laboratory bench was obviously a more familiar and congenial task to the planners than building and servicing a township.[6] Then later on when Woomera began to take physical shape, labour and resources were funnelled into the construction of the ranges and the lower priority housing program lagged far behind schedule. Despairing of ever getting their families on to the site, the workmen of the private contractors set up a rather squalid shanty town at Pimba outside the prohibited area, which soon acquired a penumbra of the humpies of detribalised Aborigines. In the village long waiting lists and doubling-up were endemic for years. In June 1951, for instance, seventy-eight families had been waiting months for one of the ninety houses inching their way to completion. By 1958 any sort of accommodation was so critically short that the trials program was being wholly determined by how many beds were available in Woomera night by night. Even in 1970 houses, still in short supply, were being allocated by a complex points system with credit being given for the number of children and completed months of service. Only the most senior staff could jump the queue into an 'appointment house'; for the rest it was bachelor quarters in the mess for an indefinite period, sweetened by a free commuter air ticket to Adelaide every other weekend. Some classes of worker had no housing privileges at all and the married ones could never hope to get their families into the village. Among these were photographic assistants who manned the cameras at the Range and were indispensable to the trials.

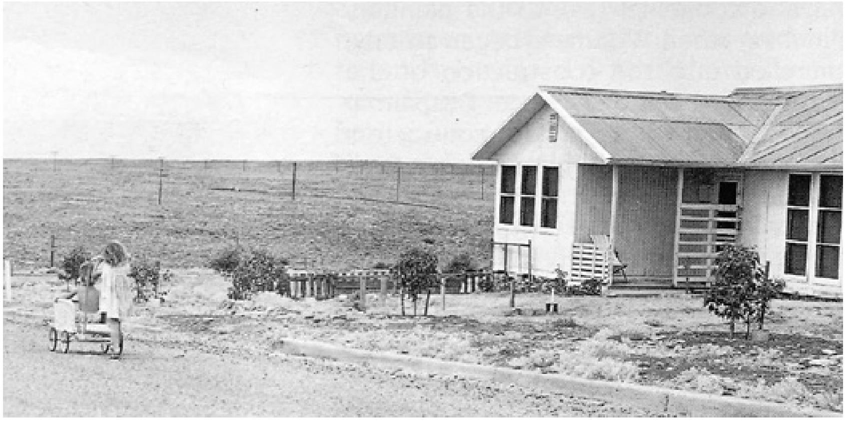
As a stopgap measure it was proposed to convert some old army huts into 'dwelling units' of one or two bedrooms by partitioning them internally and installing extra plumbing. But taking into account dismantling them, transporting them to Woomera and modifying them to suit, the cost would have been about £2000 for each very inferior dwelling—ones where a tall man's head would be constantly scraping the ceiling. Evetts quashed the scheme, 'married personnel stationed at Woomera would be required to live for at least 3 years in this type of quarters. I consider that this would be asking too much especially taking into consideration the trying climatic conditions and geographical disabilities of the area.'

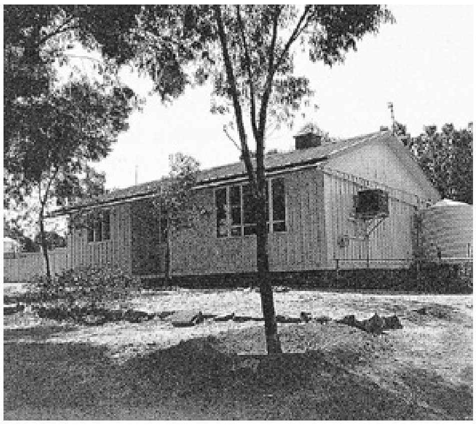
He feared that if a lot of money was put into the conversion, their future replacement would be resisted and Woomera would be left with a block of instant slums. Instead, he recommended that only single men should be appointed where possible, and married men should do tours of only a year and without their families until reasonable houses were available.[7] Nonetheless, it came about that the first detached family houses, or 'married quarters' as they were called in services terminology, were fifty-four secondhand 'temporaries', timber framed dwellings on concrete piers with galvanised iron roofs and walls brought from a dismantled RAAF station at Port Pirie. In the end sixty-seven of these were erected at Woomera and, as tends to happen with temporary housing, not only did they give good service right through the project but some of them were trucked to Adelaide after the village contracted, there to be resited, refurbished and sold at a good profit.

Of the new houses the greater number were prefabricated dwellings of three types—the Econo, the Hawksley, and the Riley-Newsum—shipped from Britain and erected in 1951 at a cost of around £5500 each. The one hundred Econos had either two or three bedrooms and were made of aluminium wall panels on a steel frame with an iron roof. The Riley-Newsums had weatherboard walls and a ribbed aluminium roof. The seventy Hawksley houses were steel framed but were otherwise made entirely of aluminium, including the roof tiles which quickly became pocked from the impact of the gigantic Woomera hailstones and had to be replaced with iron. The Hawksley was manufactured by a Hawker-Siddeley



Woomera's first houses, the 'temporaries'.





Above: A Riley-Newsum house at the edge of Woomera; beyond it the desert.

Above right: A Hawksley house, prefabricated in aluminium.

subsidiary, formed to beat swords into ploughshares by using up the sheeting left over from the wartime aircraft assembly lines. It was small, under nine squares, a little cheaper than its two competitors and was often spoken of disparagingly as 'a metal dog box' and 'a lined tin shed,' though remembered affectionately by some of those who raised their families in them. The walls were lined with fibreglass which was then a new material (the other houses used caneite, a peculiar flammable product made of compressed sugarcane) and the sound insulation was better than one might have expected given the all-metal construction. Their British origin was betrayed by their snow sills and lack of flyscreens and wire doors, and who should pay to add the latter to the Hawksleys was still a subject for acrimonious discussion four years after the first tenants had moved in. In 1961-62, this initial stock of prefabs was supplemented by fifty more bigger houses of eleven or twelve squares, with weatherboard or asbestos walls and iron roofs.

The single most common type of house in Woomera, though, was a conventional one of solid brick with plastered internal walls and an iron roof. This came in various styles such as the L-shaped design of three bedrooms to be seen everywhere in the metropolitan suburbs, and 131 of them were built between 1949 and 1954, at costs ranging from £6600 for the basic type to £11 100 for the three superior ones in the 'Nob Hill' area south of the town where lived the Range Superintendent and other most senior staff: their homes were on large blocks with gardens tended by the Department of Works.[8] The brick houses were not well built and they did not survive the project itself for long. The bricks were made locally, not of fired clay but of cement mixed with sand and gravel; their quality was poor and the plant closed after a few years. Nor were the foundations adequate for the unstable Woomera soil. The walls began to crack alarmingly after a few years, and by 1983 nearly all of these houses were scheduled for demolition. In their day, however, they were the most popular and new arrivals would scheme long and hard to be allocated one.

All together the first few years of the project saw around 500 detached family houses arise at Woomera, plus another twenty-four single residents' and visitors' quarters which were simply prefabs adapted for communal living. Once these had been completed at Woomera the stock of family houses grew little. For most residents, especially the single or childless, 'home' meant not a detached house but a flat or room in a block. More than forty blocks of one, two or three bedroom flats were built between 1956 and 1972, most of them in the boom years of the late 1950s. The peak number of 'married quarters' was reached in 1960 with 885 dwellings. In the later years the only changes were the arrival of eighty-one transportables for the American Nurrungar personnel and some ATCO houses to replace the demolished brick ones.

Whatever the construction or style, none of the original Woomera houses made much concession to the climate. Most faced east or west, so that in summer they caught both the morning and afternoon sun through their front or rear windows. The blocks of flats were more sensibly aligned with their front windows facing due north and shaded by verandas. The greatest boon was that evaporative air-conditioning did exist in those days, although the technology was primitive and so little was known about it that the village Board had to write to the chief engineer at the Broken Hill hospital to find out if it worked. Bulky Breezaire units—the first two hundred or so were donated by the British government—were eventually put in all the houses, though not without some resistance from the Department of Supply, which said they were an unnecessary luxury. The Breezaires certainly worked, but

Far left: A brick house, one with a well-kept garden.

Left: A two-storey block of flats, each equipped with its outside evaporative cooler.

they used a great deal of water and sometimes sprayed it over the carpet and furniture; also they were noisy and when first switched on smelt disconcertingly like a wet hessian sack. The rental was not cheap and they often broke down. In 1957 one householder wrote angrily to the Board that for some time now he had been paying several shillings a week for a large hole in his wall.

The family houses at Woomera all stood separately in suburban sized blocks, and what kind of garden was created out of the unpromising natural material was left up to the tenant, although the Arboretum gave away trees and shrubs generously to encourage planting. The results varied from wildly impractical sweeping lawns and rose-bushes to unredeemed claypan. The keen gardener had to be made of stern stuff to transform his desert block into a bowery Eden. The first residents with no experience to guide them thought that a little water and fertiliser would work wonders. They planted their seedlings and sowed their lawns only to see the struggling results swept away by a dust storm. So fencing and support for saplings were prime necessities, and to achieve anything really worthwhile far more thorough preparation was needed. To make a lawn or flowerbeds the thick, sticky salty clay which was Woomera's soil had to be dug out to a depth of 25-30 centimetres and backfilled with the red dune sand delivered free by the Department of Works in 6 tonne loads. Planting trees and shrubs was even more demanding, for they would only adapt to the salt in the subsoil if they were nurtured carefully early on. The Arboretum's instructions were to dig out a cubic metre of clay and replace it with sand. Digging down into the solid clay needed a pick or crowbar and a good deal of stamina. In any case it was wise not to follow instructions too closely, even though your efforts were supposed to be inspected and passed before the Arboretum would issue you with free seedlings. A deep sand filled hole was simply a sump in which the trees' roots stood in water that could not drain through the impermeable clay, and it is surprising that so many survived this thoroughly unsound advice.

Vegetables could be grown, though here the main problem was getting enough humus into the sand. Of course it could be done. You could use old railway sleepers from Pimba or flat gibbers gathered from the donga to make raised beds of well drained sand. If you had access to it, you could add countless bags of sheep dung from beneath the shearing sheds of the neighbouring stations. You could import worms, dig in every scrap of household waste, and use sludge from the sewage farm which spontaneously grew tomatoes and cucumbers from seeds passing through the digestive tract—some refused to eat the resulting crop. By such means, with a great deal of sweat and patience, a couple of stunted shrubs and mass of saltbush could be turned into a productive garden:

> Every type of vegetable imaginable was grown—the cauliflowers and cabbages reached gigantic proportions in the sunny climate and rockmelons were most impressive too (although one excellent crop was completely wrecked in a bad hailstorm). Flowers and herbs were also grown, and people living nearby and friends shared the produce from the garden, including eggs and live fowls and ducks.[9]

While the physical setting of life at Woomera was never more than utilitarian, it certainly had plenty of material compensations. Wages were very high and even in the early days a tradesman could be earning £1000 a year with his remote locality allowance and abundant overtime. And there was little to spend it on. Woomera was a miniature welfare state where most commodities, services and entertainments were subsidised in one way or another. The houses may not have been particularly comfortable but to rent one only cost about 30 shillings a week; no council or EWS rates had to be paid and electricity was very cheap. If it wished to do so, a parsimonious family could get by with hardly more personal possessions than its clothes. You did not even have to wear out your own furniture; the government did not want it taken along and as an incentive would store it free in the city. Each £100-worth of government furniture cost only an additional £10 a year to rent though if you did not cultivate the furniture clerks—people with some power—you could be landed with a pretty motley collection. Nor was it difficult to lay hands on materials for little domestic improvements like pergolas, trellises and summerhouses. The village dump was a popular source of such treasure trove and going there was practically a social outing:

> I used to go out to the rubbish dump with rubbish and pick up a load of stuff to bring home. One day they were burning blankets, perfectly good blankets that had been declared 'obsolete'. Yet people down in Adelaide were fairly screaming for them.[10]

Woomera's population began by being extremely unbalanced demographically, and it long continued to be so. Even in 1972 four men lived there to every woman, and the mean age group was still under 30 years, just as it had been at the beginning. It was so low partly because of the numerous and thriving young children. The first 'official' child born at the Woomera hospital was a Susan Prout, but before any proper midwifery services were available a number of women had refused to leave the area and had given birth there, including one in a Holden car. Plenty of babies came subsequently. Late in 1951, 59 of the 210 married women were pregnant simultaneously, and after that the birth rate climbed to a point where it was the highest in Australia. At first the village children travelled on an old Blitz truck down to the tiny school at Pimba, which was overwhelmed by the twenty-five or so new arrivals. Then in February 1950 the school opened in the Church Hall and the Pimba school closed. Eventually the educational facilities in the town expanded to three kindergartens, a Catholic primary school, a state primary and high school of good repute

A kindergarten group in 1963.

A 1951 primary school class.

and an adult education centre. Though older adolescents suffered from the lack of social range and stimulation, for small children life could be paradisial:

> There were the sandhills at Shell Lagoon, which provided an outlet for excess energy—a board was carried to the top and used as a sled on the steep slide down to the bottom; the hills to climb at Wirrappa, and perhaps a fruitless chase after a family of emus or kangaroos; picnics at Lake Hart, with its old disused salt mine and one solitary unmarked grave, where they could walk out on the 'lake' and find twigs and other treasures encrusted in salt; days at Andamooka, 'noodling' for opal chips on the slag heaps at the top of the mines; trips to Eucolo Creek with its Aboriginal rock carvings—searching for artefacts at long-deserted Aboriginal campsites, feeling a sense of awe at their age and the ingenuity of the people who had fashioned these primitive but efficient implements. There was Dog Leg to visit, where it was relatively easy to find fossils, and the old coach road over rough gibber country, up and down the banks of dry creek beds, past Island Lagoon Creek to the old coach house itself, with its rusted iron bedsteads still standing, and its well, with old buckets still lying beside it. Everywhere the incredible age of this country seemed to dominate one's consciousness, and the children grew up in two contrasting worlds—the modern world of rocketry inside the village and the ancient land outside.[11]

No doubt Woomera deserved the accusation that it was a man's town, but outside the messes at least most of the men were family men, and the atmosphere was strongly domestic. Cathy Barber, who spent all her childhood in Woomera, recalls fondly that always something was going on, some new plan afoot.[12] Many of the adults' clubs had junior branches: football, soccer, basketball, cricket, swimming. A Youth Centre built late in the 1960s was the scene of dance marathons and pop concerts, and a Baden-Powell Hall housed the Scout and Guide troops. The stress was very much on active, sporting recreations, for television did not come at all until the last years of the project and even then it was the ABC channel or nothing. And children suffered few physical constraints. Even the most punctilious parents did not need to give much thought to their child's safety. Woomera was so secure that year after year cars would stand in drives with the keys in the ignition, and front door bolts would grow squeaky from lack of use. Minor vandalism was sometimes a problem, but serious crimes like assault or abduction were inconceivable. Children could and did go about unaccompanied at all hours, go to the cinema, wander unconcernedly in and out of houses and treat much of the village as an extended family. This casualness led a Department of Community Welfare social worker to conclude unfairly that 'some of the parents in Woomera do not seem to care about their children' though it certainly happened regularly, as she also noted, that children were left alone in their houses at night.[13]

If young children were ubiquitous at Woomera, single women were at a premium. Late in 1949 they were represented only by four army nurses headed by Captain Vicki Hobbs, ten typists and telephonists, thirty waitresses at Woomera West and the few Computers who came up from Salisbury during the week for trials. Woomera's reputation as the haunt of lean and hungry single males meant that the Computers were not allowed in without a

A group of visiting Computers from Salisbury, kitted out for trials, in front of the old Senior Mess building in 1950.

severe struggle with the authorities, in which George Hicks, the bomb ballistics expert, was their champion. He recalls:

> The computers suggested that they were quite as capable of tracking aircraft and bombs with kines as the men were and why shouldn't they go up for a week's trials and then spend the next week computing the results of 'their' trials—*a personal interest in what was going on that was very praiseworthy. But you can imagine the reaction of the Victorian-minded administrators of Adelaide: no women at Woomera—it wouldn't be safe with all the military about etc. etc.
>
> But eventually Salisbury was won over:
>
> A sleeping quarter standing on its own was surrounded with a high corrugated black iron fence in which a stout iron gate was fitted with a padlock and chain, and was prepared for female use. The girls were kitted out in Army dress—wideawake hat, khaki shirt and slacks, heavy brogues, leather jerkins for cold weather—they looked terrific! Each party would be in the care of one of the senior girls, who would lock the gate at night and be prepared to defend the key with her life—only opening up in the morning ready for breakfast. So it was done and everything worked out smoothly to the relief of the administrators. Of course, that was only a beginning—the hospital had to have nurses, the Officers needed telephonists and typists. When brick and concrete replaced wooden huts, families moved into the village: schools, playgrounds and all the appurtenances of a civilised society became necessities and Woomera was no longer chauvinistic! Nor was it ever quite the same again.[14]

Permanent women's quarters and a mess did not come until 1952 under the first housekeeper, Mrs Keidan. For a young woman searching more or less deliberately for a husband, Woomera was a buyers' market. For her sociable sister in no hurry the pace was killing.

But most women at Woomera—250 of them by 1952—were housewives with young families. To the outsider of the time the lives of these families appeared quite enviable. Were they not immune to all the pressures and frustrations of post-war Australia, with its housing crisis and economic dislocations? A visiting journalist, dubbed by her magazine 'the first woman reporter to visit the rocket range' painted a glowing picture of an egalitarian society where the biggest problem in life was having to buy meat sight unseen, ordering clothes of dubious cut by mail, and dealing with the drying effect of the wind on the hair and complexion. Obviously this is a fatuous oversimplification, but any attempt to assess the quality of life at Woomera must rely perforce on anecdote and reminiscence. Hard data are lacking, for unfortunately neither of the two proposed sociological studies of the town—one in 1962, the other in 1973—came to fruition.

It is fair to say, however, that those who liked the atmosphere of Woomera tended to like it a lot. It was a place which encouraged deep commitment, since it demanded a good deal in one way or another from everybody. Some actually grew fond of its unprepossessing physical setting: they admired the desert sunsets, the astonishing night sky in the clear air, the gold, pink and white everlasting daisies and the Sturt Peas which appeared virtually overnight after rain. Such people, most of them no longer at Woomera, stress again and again its comfort, peace and security, its neighbourliness and openness to outsiders so different from the typical inward-looking country town. Some had gone to Woomera expressly to escape inconvenient problems in the city, but most people, the civilians especially, were waifs, only too conscious that their relatives were far away and therefore eager to make friends to take their place. So the village quickly developed a close knit texture of friendships based on the value of having a helpful neighbour at your elbow. The experiences of many ex-residents have become rosy in memory; life in Woomera has been sublimated into a sort of warmly glowing ideal of suburbanism as it might be, or ought to be:

> If your car broke down you got out and within seconds somebody would say: 'Something wrong? Can I help you?' When I was tied to home, pregnant or with small children, if I wasn't outside by ten o'clock one of the neighbours would knock on your door: 'Are you all right? I haven't seen you this morning.' Here in Adelaide you could be dead for three days and nobody would notice anything. If you went up the street and you didn't have a car your next door neighbour would say: 'Oh look, you haven't got a car. I'm going shopping at such and such a time; come with me.'[15]

No doubt size had a lot to do with this cosiness. After all, even at its largest, a long-standing resident of the village could know practically everybody, at least by sight. Unavoidably, the private life and the life of the workplace overlapped in a way more like a town of medieval Europe than of modern Australia. A foreman, for instance, could hardly avoid having an intimate knowledge of his workmen:

> I knew my staff probably better than they knew themselves. I knew their habits, their likes, their dislikes—and not only theirs but their wives' and their kids' as well. And this was true because you were mixing socially. I don't think you'd strike anywhere else in Australia quite like it. It was really unique.[16]

Such compulsory intimacy was not of course to everyone's taste. For some temperaments Woomera's positives could easily be transmuted into negatives. The concern of your friendly neighbours might seem offensive prying: certainly adulterous liaisons or marital disharmony were matters of public relish to a degree unimaginable in the city. The pleasant sense that you had no material worries could become a chafing sense that your whole life was controlled by inept bureaucrats who, as one ex-resident phrased it, had at last found a pond small enough to turn them into big frogs. When even the films you could see had been selected for you, it was not hard to feel like a factory hen, warm and well fed in your little wire cage. The hearty emphasis on sport and community could look like the worst kind of ocker philistinism, underlined by the dearth of cultural life, a lack of bookshops and plays, concerts, galleries and specialist shops, a wide choice of films and friends, and the chance to live out more than the few roles that your neighbours knew so well. For such private natures, Woomera could feel like a cross between one of those relentlessly cheerful British holiday camps and a boarding school in the country. The social life could be petty and bitchy, the heads of many service wives in particular being filled with nothing more than trivial gossip about the ranks and promotional chances of their husbands. The pecking order loomed large, exacerbated by some pointless privileges of rank. For many years the receptions for VIPs excluded practically all the professional and technical staff, even those working on the very project which the VIP had come to see. On one occasion an engineer was demonstrating a new tracking radar to a VIP. As he took his leave the latter said cheerily, 'See you at the party tonight, then!' 'No Sir' was the only possible answer.[17]

Others found the magnified and inescapable suburbanism grating on their nerves. Woomera could be stifling if you disliked the inevitable small town diet of scandal and trivia and demanded more of life than the round of school and club committees, church functions, handicraft classes at the Country Women's Association, or helping to run the Guides. Such Madame Bovarys—more of the malcontents were women than men—were not encouraged; those who sighed vocally after the bright lights might be advised with scant sympathy to try a bigger globe in their lounge room. Woomera could be cruel indeed to those women who were much alone, who had little to do and who consequently suffered from feelings of aimlessness and anomie. The rate of divorce is not known, but is generally agreed to have been high. Psychiatric problems were by no means unknown and were possibly more common than in the city. Little could be done for such cases in the village, especially in the days before effective drug therapy. Dr Greg Markey, who practised there from 1954 to 1958, recalls how one woman, a clerk, developed acute schizophrenia and had to be taken to Adelaide by plane for treatment. She escaped from his care in King William Street and sought the aid of a policeman, whose suspicions about the doctor's motives were not easily allayed.[18] Incipient or chronic alcoholism was the greatest social scourge. Heavy drinking was practically a way of life for everyone except confirmed teetotallers, and the chief aim in life of some women was to get their husbands transferred before they were sacked or succeeded in their apparent determination to drink themselves to death.

But even at their worst such aspects of Woomera life were just a few dark threads running through a brightly coloured tapestry. At its height Woomera was a pulsing place, busy and self-confident in a way that is now rather hard to imagine. Very few people had any qualms, or even thought twice about living in a place largely devoted to the arts of mass destruction. Most people were surely happy and active there most of the time; the men convinced of the value of working at their world-famous centre and their wives living through them and immersed in family concerns. A young population full of high spirits kept morale high and readily tolerated eccentricities and jokes. One gatekeeper, confronted by an awkward arrival, would reach down inside his shirt and bring out a fearsome looking but tame goanna. Partly drunk workmen were instantly sobered by having a metre long lizard with a forked tongue poked in their faces.[19] One of the most effective practical jokes was at the time of the first Sputnik in 1957. Everyone was outside scanning the night sky for the tiny moving star which was the satellite. Archie Ryan, a weather observer in the Met. section, took a hydrogen balloon, fixed a flashing light to it and launched the contraption from the roof of the Senior mess. It drifted over the top of the Staff mess, where drunken shouts of excitement attested to its authentic appearance.[20]

LIFE IN THE WOOMERA MESSES

As this anecdote implies, the messes were the social heart of Woomera. The village contained no hotels, no pubs, no nightclubs, no amusement arcades, no skating rinks, no jazz cellars. Except for a brief interlude there were no restaurants. The only attempt to provide one was a dismal failure. In February 1962 the Board proposed that a formal restaurant of good quality should be established in the village. It was not to be segregated like the messes. The suggestion was an excellent one; it is surprising, in fact, that it had not been made earlier. The proposal was well received by the community and elaborate plans were made for sixty-eight tables, a bandstand and a dance floor. A competition was held to choose a name. It was won by a little girl who suggested the 'Mirage', and her prize was to be a free dinner for four when the restaurant opened. She had plenty of time to reflect on the appalling aptness of her choice, because the child of nine had grown into a sturdy adolescent of fourteen before she sat down to table. When the Mirage did at last thicken into reality, one could enjoy there those familiar French dishes 'Entrec'ote Mirabeau', 'crème of champignon' or, for those for whom this was too exotic fare, there was the down-market 'nut sundae' and 'pork sausage and mashed potato'. Not surprisingly, after nine months of this kind of thing the Mirage shimmered off into oblivion.

The failure of the Mirage was due to managerial ineptitude, not the unsociability of its potential patrons. The villagers were isolated, with a strong sense of solidarity, and the dearth of packaged entertainment encouraged the habit of making their own fun. Such circumstances guaranteed that the town's social life would be copious, energetic and stimulating, and so it was; sometimes indeed it was riotous and frenetic. One could seek the company of one's fellows at the many private parties or enjoy a quiet drink in the Bowls or Golf clubhouse, but much of the social life revolved round that venerable institution, the Woomera messes. In the messes were merged the functions of club, restaurant, hotel and bar. The catering and accommodation was looked after by the Department of Supply, but recreation and the bars were controlled by a committee elected by the members themselves.

They were limited by charter to the quantity of funds they could accumulate, and the surplus had to be returned in the form of libraries, lavish sporting facilities, low prices and occasional free drinks. In their heyday each mess sponsored a sporting team, and also made donations to charities. Cinema shows, dances and parties abounded, often with imported bands or entertainers. Though the facilities grew quite lavish the mess buildings themselves were hardly luxurious, except for the lowest ranking one, the Junior Staff Club (the 'Jazza') which in July 1961 moved into new purpose built premises. Inside was a bar, a ladies' lounge, beer garden, library, billiards room, games room and cafeteria. At its opening the entrance featured an indoor garden with a waterfall, planted with candle pines and golden cypress pines. The general effect was said to be of 'a view from a Roman villa across snow clad Alps'.

Woomera was not, overtly at least, a permissive town. As we have seen there was practically no serious crime, but quite minor offences could attract penalties whose actual effect was multiplied by the closed nature of the community. Being sacked, for instance, almost invariably meant losing your home and therefore being forced to leave the town; and dismissal could follow from rather trivial delinquencies, or even the Superintendent's private notions of immoral behaviour. One ex-resident recalls:

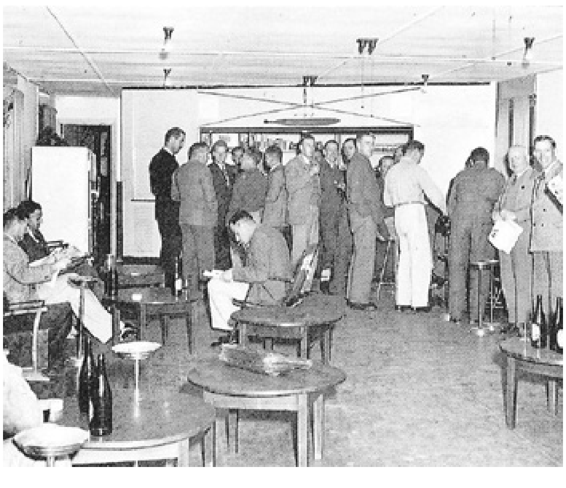
> We had a chap come here as a storeman and I think on about the second night after he arrived he got a bit drunk in his mess and he was dancing with another bloke and hugging and kissing in the middle of the floor. He was on the next plane out.[21]

But if Woomera could be puritanical, it is characteristic of the puritan ethic to tolerate, even license, places and times where anarchy and excess can flourish unchecked. Cromwell's England had May Day: Woomera had its messes. The behaviour there sometimes descended into drunken brawling and mindless damage to the fittings. Behaviour that would certainly have drawn the attention of the police elsewhere was tolerated and frequent replacements of smashed furniture winked at even when it was no more than vandalism, as on a notorious occasion in the Staff mess when a pint of beer was tipped into a grand piano. Men who had little taste for the somewhat starchy atmosphere of the Senior Mess could by invitation go slumming in the Jazza, which in the 1950s was housed in a number of condemned wooden huts and had a reputation for the roughest kind of merriment:

> I used to go down to the Jazza every Friday night, buy a pint of beer and stand in a corner to watch the fights . . . Oh my word, there were some good fights. At Christmas and New Year they had some especially good 'do's' there; the floor would be awash with drink. I reckon they set an Australian record for beer consumption; I forget how many 18-gallon kegs were consumed: something like 130 over the weekend. When the messes made profits, they would throw a free party every month or so to use up the funds and men who were used to beer would drink Drambuie and pass out in droves.[22]

Such behaviour was by no means restricted to the lower orders of the Jazza. Protocol in the Senior mess may have been stiff most of the time but on certain licensed occasions all decorum was cast aside. The most notorious of these occasions was the annual members only 'dining-in' night. For the first part of the evening the appointed President of the mess would keep things under tight control during such ageless ceremonies as the drinking of foolish toasts and passing the port. At a set point, however, the President retired and 'Mr Vice' began his rule. Anyone of mild disposition was well advised to retire as well, for the only role of this functionary was to whip up the by now drunken members into ever

The Senior Mess lounge in 1950 (*far left*) and twenty years later (*below*).



wilder excesses. Old service games would be played, like 'High Cocklorum' where one man on another's shoulders tried to unseat his opponent by any means, fair or foul. This could lead in turn to general rough-housing, broken jaws and the smashing to smithereens of the dining chairs and crockery. Such orgies of destruction were in effect connived at by the authorities, who were prepared to view them as keeping up the mess traditions.

A milder affair was the mess birthday party, an open occasion with many guests; nonetheless, it was not unknown for such parties, often in fancy dress, to last for a whole weekend. Only Sunday evening was sacrosanct: 'Nobody dared visit anybody on a Sunday. Sunday night was rest night. More or less sobering up for Monday.'[23] On one particular occasion when the Works team won the football Grand Final, the entire team and many supporters visited the doctor the next day, who issued them all with certificates specifying 'morning sickness'. One *bon mot*, frequently quoted with bravado, was: 'I'd hate to be a teetotaller; you'd wake up in the morning knowing that was the best you were going to feel all day!' The consequences of this philosophy were much exacerbated by the male-oriented, hard-drinking ethos of the messes, where a standard drink was potent gin squash dispensed by the jug.

THE MESS CASTE SYSTEM

The messes, like all human institutions, evolved and mutated over time but they never entirely left their origins behind. They were the oldest social organisation in Woomera, being in their first primitive form nothing more than large huts surrounded by single men's quarters; places where men could eat and try to forget the flies and dust for a while with the simple amusements of cards, table tennis and beer. It should be borne in mind that the first permanent staff at Woomera was practically all servicemen. At the beginning of 1949 the staff consisted of 238 officers and other ranks and just three civilians (excluding the Department of Works building workers). All three services supplied career officers to fill the top positions of authority, so that at one time, for example, the Range Superintendent was an Army Brigadier, the officer in charge of the Range was an RAN Commander and the Senior Personnel Officer was an RAAF Squadron Leader. The same pattern could be found throughout the administrative positions for the first few years, but after that the armed forces representation began to fall away quickly. By February 1950 there were 487 officers and other ranks, and 156 civilians excluding the construction force, and by August 1951 there were 434 officers and other ranks, and 284 civilians. The ratio swung much further in favour of civilians after that, partly because the civilians had longer postings and were more likely to have their families with them. For much the greater part of its history Woomera was a town of engineers and administrators, rather than a garrison town; but in its formative years its messes were

Senior Woomera staff in April 1951. At that time civilians were beginning to replace servicemen. Brigadier Neylan is at the centre of the front row.

given the indelible impress of the Service hierarchy. Originally three messes were established in the village (plus three more at Woomera West and two at Koolymilka), socially stratified according to the age old pattern of military life into Officers', Sergeants', and Other Ranks'. Because the civilian domination of the town was a gradual and imperceptible process, it was natural for the new arrivals to be allocated to the 'appropriate' mess.[24] At first sight it seemed straightforward enough: professional men on a salary would attend the Officers', tradesmen and foremen the Sergeants', and labourers and industrial workers the Other Ranks'. In November 1953 the new descriptives of Senior Mess, Staff Mess, and Junior Staff Club were substituted for the military labels, but the rules of membership and particularly the rules of exclusion were no less strictly enforced for all the change of name, especially in the early years. For a long time it was allowable for a man of a higher mess to be a guest in a lower, but the reverse was impossible, even by personal invitation. When after a stormy meeting in 1961 the Senior Mess rules were changed to permit guests it was noted that the members most adamantly against this reform were the parvenus who had just been promoted to it themselves. The caste system was rigid; nearly as immutable as that of the Alphas down to Epsilons of Aldous Huxley's Brave New World. According to one story an exam assessor visited the school at Woomera and wanted to put in an adverse report on a student. She had this perhaps apocryphal exchange with the headmaster:

> 'No, no, that won't do. You mustn't say that.'
> 'Why not? The boy's work is mediocre, and I ought to say so.'
> 'No, I'm sorry, but it really won't do at all. You see, his father's in the *Senior Mess*!'

As in Huxley's fantasy, it was rarely necessary for the rules to be strongly policed: after a few years obeying them was practically instinctive. Social pressure or at most a quiet word in the ear from an official of the Mess Committee was enough to enforce standards of dress and the other protocol. The most effective guard against 'aliens' coming into a mess was the acute social discomfort it produced, even when the visit was on a permitted occasion. Since segregation was universal and commonplace not even the most rebellious wanted to drink amidst a sea of unfamiliar faces, especially if one of them held the disapproving stare of his boss.

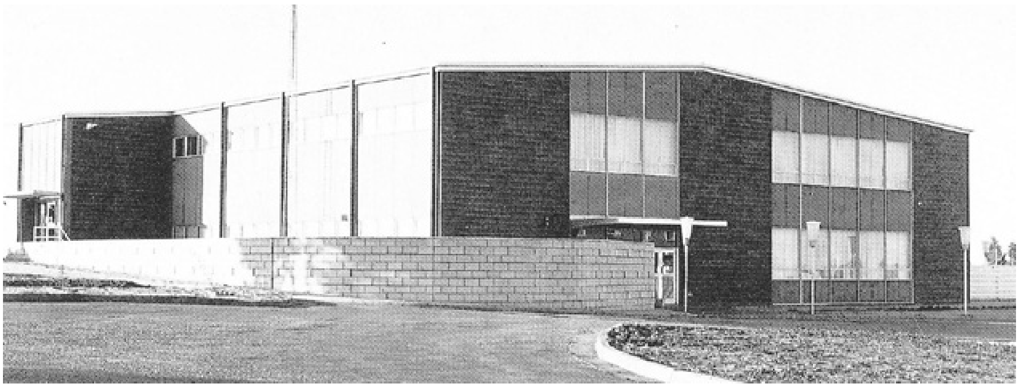
This is not to say that civilians were easily made to fit the Procrustean bed of the three tier system: six fat files held at Woomera labelled 'Mess Membership' are solid evidence to the contrary. Even before the messes were renamed, Range Superintendent Pither had to report 'considerable discontent and embarrassment caused by the absence of firm rules'. As a remedy he proposed the introduction of a straightforward system based on salary, with a basic pay of £860 and £770 per annum setting the minimum levels for membership of the Officers' and Sergeants' messes respectively, men on a lesser wage going automatically into the Other Ranks'. Yet he refused to let salary be the final arbiter in a few cases. Clerks, for instance, were poorly paid and some should have been demoted from Officers' to Sergeants' whereas foremen would have had to be promoted the other way. This offended the Superintendent's sense of the fitness of things. To him, senior clerks were honorary officers; foremen certainly were not, so he proposed leaving these grades where membership accorded with status.[25] From the start, then, and despite avowals to the contrary, the allocation of messes, while clear enough in most cases, always had an arbitrary flavour about it. There were always enough fringe cases or special exemptions to generate an inordinate amount of paperwork and to require on occasion the judgment of Solomon. What arcane principles were applied to decide that a visiting piano tuner was Senior while a visiting tax agent was Staff Mess? What should be done about men who wished to decline the honour of promotion to a higher mess? (Sometimes they were allowed to, sometimes they were not, according to no discernible principle.)

Each time the system was tinkered with to correct one lot of anomalies, more were created along with a good deal of hurt, resentment and social embarrassment. In one clumsy move in 1954, some of the Peace Officers, who had more responsibilities than ordinary state policemen and whose security work was obviously a lot easier if they were generally respected, were downgraded to the Jazza. 'As a natural consequence', their spokesman said, 'the majority of members have lost all desire to do anything beyond the letter of their post orders and that often somewhat dispiritedly'.[26] This appeal fell on deaf ears for a long time before they were reinstated after a dignified campaign lasting nineteen months. Constant pleas came from other government departments, unions and professional associations to have men reclassified. Campaigns were waged on behalf of men such as the Head Cook of the Senior Mess who, responsible though he was for 1500 meals a week and with eleven staff beneath him, apparently rated no better than the Jazza. Well-qualified technicians of the Postmaster-General's department, regularly brought to Woomera to work on the telephone lines, were outraged to be put in the Jazza and took their case right up to the Minister for Supply without success. After that, as the Director of the PMG in South Australia had to inform LRWE with all proper regret, 'under present staffing conditions, it is not possible to undertake any new commitments which depend on the work of technicians.' In plain language, Woomera was boycotted.[27] One of the oddest pleas came from the accountant at Woomera. Urging the merits of a Debtors' Ledger Keeper whose job was to chase up delinquent accounts, he said in all seriousness that 'Senior Mess status for the officer would be more fitting and would assist him in carrying out his duties'.[28] Segregation applied, in principle at least, no less to outsiders than to residents. Since the village had nowhere else to put up visitors, official parties—even trials teams up from Salisbury—had to split up. This was so obviously inconvenient that sometimes people received temporary and strictly unofficial upgradings to hold a group together. Some of the contractors who sent men to Woomera put them down automatically as Senior Mess status; others defined their personnel more modestly and put most of them in the Jazza. One firm even had the impudence to order the VIP quarters for its test pilot. Wrestling with these problems, the Range Superintendent of the day, Jack Newman, arranged a conference to try to sort out the membership qualifications, 'which at present,' he conceded in his blunt Navy way, 'are haywire'.[29]

It may seem remarkable that such a system should have survived for so many years, more reminiscent as it was of India in the heyday of the Raj than of the egalitarian outback. Yet it was not unpopular. Many men liked the warm feeling of being surrounded by others at their own level. The servicemen in particular—and the military were a large minority until the early 1970s—liked to drink in unbuttoned ease where there was no risk of having to salute or call anyone 'sir' . It is true that even in the early 1950s the High Council of Public Service Associations was complaining that the messing system was undemocratic, unfair and divisive. The Establishment never denied this charge. It simply took the pragmatic stance that the joint project could only afford to provide one set of messing facilities for servicemen and civilians, and, 'Service personnel have resisted any breaking down of the standards'.[30]

The messes were of course segregated not only by status but also by sex. Single women at Woomera, be they lowly laundresses or elevated computers, were lumped together in a separate mess, originally called the Noorabalya Club, which had no formal divisions of status. (This was more a matter of expediency—numbers were relatively small—rather than because femaleness was deemed to override all class distinctions.) Housewives naturally took their husband's mess status, though they were only allowed to be associate members. Up to the late 1950s this meant in effect that they were barred from the mess except on particular occasions such as party nights, or the one night of the week—usually a Saturday evening—when dinners by candlelight were put on. In later years when the rules on female guests were relaxed, wives were still kept out on 'members only' nights, though they could be entertained in the Ladies Room at any time. More complex problems arose when a working married woman had a different mess status from her husband. A common case was where, say, a secretary was married to a man of an industrial grade (Junior Staff Club). In such cases she descended to his status; he could not ascend to hers.[31] This situation appears to have been the only one which is remembered with much resentment at Woomera, though it was not until 1973, over a complex case of a married female teacher who was being forced out of the mess in which she was temporarily living to take up quarters in the lower mess of her husband, that the cry of discrimination first went up, with letters to the Prime Minister, Gough Whitlam. With that even the male bastion of the Senior Mess caved in and allowed women members, not without the sour comment from Director Don Woods that 'much as we may deplore it, discrimination on sexual grounds is no longer 'on' . . . we cannot logically bar women from membership of the Senior Mess.'[32] Logically, of course, they never could; only a change in social attitudes exposed the illogicality for all to see.

But it was a Pyrrhic victory for those women eager to enjoy their new rights. Almost a decade earlier the village messes had been supplemented by the ELDO mess, a large building like a modern motel paid for from ELDO's funds to keep the Organisation's personnel together and to avoid the problems of having to fit them into the Australian class structure.



The ELDO mess, now the only survivor of five Woomera messes in the peak years.

At first this mess was open only to ELDO employees and their guests, but in due course it swallowed up first the single women's mess, then after the ELDO program ended the Staff Mess (June 1974), the Senior Mess (February 1976) and finally late in 1977 the Jazza as well. With these amalgamations all the social and sexual distinctions of messing in Woomera vanished. The ELDO mess became the social centre of Woomera, welcoming all residents; and though some older employees resisted the changes and later complained that ELDO was impersonal and lacking in atmosphere, it succeeded well enough to contribute $23 000 of profits to the beleaguered Woomera Board the year after the joint project ended. As for the old mess buildings, they were demolished except for the Jazza which became storerooms, and today only some crumbling foundations mark the sites where the liveliest of Woomera's institutions once stood.

POWER AND AUTHORITY IN THE VILLAGE

If the messes supplied the framework into which much of Woomera's social life fitted, it was the Woomera Board and the edicts of the Range Superintendents that most formed the pattern of the villagers' domestic lives. A good deal of thought went into planning the administration of Woomera. The main principles by which it ran were first formulated by an interdepartmental committee consisting of the first Range Superintendent, Brigadier Edgar, and representatives from the Departments of Supply and Development, the Interior, Works and Housing, and the Treasury. The two meetings of this committee on 17 and 24 May 1948 were the most fateful in Woomera's history, for it was the decisions made then which established the basic official structure of life in the village and determined how its services were going to be supplied. The first meeting, for example, grappled with the problem that the town's population would consist for some years of a possibly uneasy blend of officers and other ranks of the three armed forces and scientists and engineers, both Australian and British. The question of military authority had already been solved by making the highest office at Woomera, that of Range Superintendent, a three- to five-year appointment from each of the services in turn. But something more obviously democratic was required for the civilians and to administer the day to day business of the village. In considering this thorny problem, the committee was strongly influenced by an organisational chart produced by Brigadier Edgar of the United States Test Station at Inyokern, California (later the Naval Weapons Center China Lake) which even then was a large and flourishing place. This community was headed by a partially elected Board of Administration through which matters could be processed for consideration by higher authority. The general impression was that this worked admirably, and the committee concluded that it would surely work at Woomera as well.[33] It is fortunate that this proved to be so, because the nascent 'Woomera Village Executive Board' (as it was initially known), though hampered at first by inadequate staff and buildings, quickly acquired a formidable agenda. Items on it for discussion in 1949 alone included plans for converting administrative buildings to a hospital; progress in kerbing, paths, and road sealing; the need for an incinerator and a complete sewage plant.

Brigadier H. C. Edgar, first Range Superintendent, but only for a few months.

In its first years the Board had an interim form of appointed members only. Its formal existence began in October 1951 with the election of three members to represent the villagers. In some ways the Board and the Administration together constituted the Woomera 'town council' with the Range Superintendent filling the role of Mayor; but the analogy is

Woomera's 'town council', the Board, meeting in temporary quarters in the old theatre in 1952.

not a particularly good one for it takes no account of the peculiar nature of Woomera. The councillors could not be elected and the council's expenditures paid for by the townsfolk out of their rates and land taxes, for there were neither land-owners nor home-owners in the village. The only owner of property was the Commonwealth, which in effect paid the rates; and all the responsibilities of local government devolved upon the federal Department of Supply.

Although some degree of democracy was ensured by the elected members on the Board, the formal relations between the Board and the Range Superintendent were rather like those between a military governor and the Executive Council of a colonial administration. Like such a council, the Board could only advise; and, although it was not usual for the Superintendent to reject the advice, it was not unheard-of either. In practice it was the Range Superintendent who wielded the greater power. Many of his duties were ceremonial and social. He and his wife (it helped if he had a wife) had to open dozens of clubs each year—shoot the first pistol, kick the first football, throw the first bowl. Then he had to give many addresses, sometimes two a day, and he had no speech writer or press secretary to help him. Brigadier Dick Durance, a warm sociable man who loved the role and was good at it, remembers:

> I used to get a card about playing card size and I would jot down a few key words. Once I was opening the Guides. I remember wondering what on earth I could talk about. I thought—'tolerance'. As long as I had a few words down I could get up and talk about refugees, people of different cultures, hands across the sea—clichés by the bucket. In the end all they wanted to hear was a noise, then whatever it was opened up, and that was that. You arrived in a dirty big car, a few drinks, a bit of old boy chat, and away you went.[34]

The exact degree of autocracy exercised by the Superintendent depended more on the personality and style of the incumbent than anything else. Some felt and acted as though they were administrators, public servants: the third Superintendent, Group Captain George Pither, was very much in this mould. In the general view he was a weak man of no special distinction, who laboured under the nickname of 'dither Pither'. Others were men of colourful and strong personalities who stamped their impress on village life. As so often happens, the times produced the man in Pither's successor, Captain Jack Newman, RAN. 'Captain Jack' was a complex and dominating character who steered the village though the turbulent years of the later 1950s almost as if it were a vessel on the high seas. Hawk-faced and dry of wit, Newman was respected and so popular that when he left in June 1959 a team of harnessed men dragged him in his car to the airport. Newman's great gift was that he could communicate well up and down the line, and this stood him in good stead when his streak of authoritarianism led him to take stern and potentially unpopular measures.

RAAF Croup Captain G. A. Pither.

Something of Newman's style can be seen in his handling of a 'scandal' which broke in April 1958. An engagement party at Woomera was turned into a pyjama party and some perfectly innocent photographs were taken openly by a friend of the couple. He then lent them to another RAAF man who surreptitiously sent them down to one of Adelaide's tabloid weeklies, *Truth*. Not much gossipy Woomera news came into the hands of editors in those

The team of men that dragged Newman's car to the airport on his departure in June 1959.

days, and the pictures quickly appeared with the participants' faces blacked out under the headline 'Woomera Wow—Not all Rockets on the Range'. In his report Newman stressed that the party had been respectable to the point of dullness. However, he objected to the minor sentence of one week's CB meted out to the offender. He asked for the man to be posted elsewhere, 'as I consider anyone who will sell his friends is likely to sell anything, including classified information'.[35]

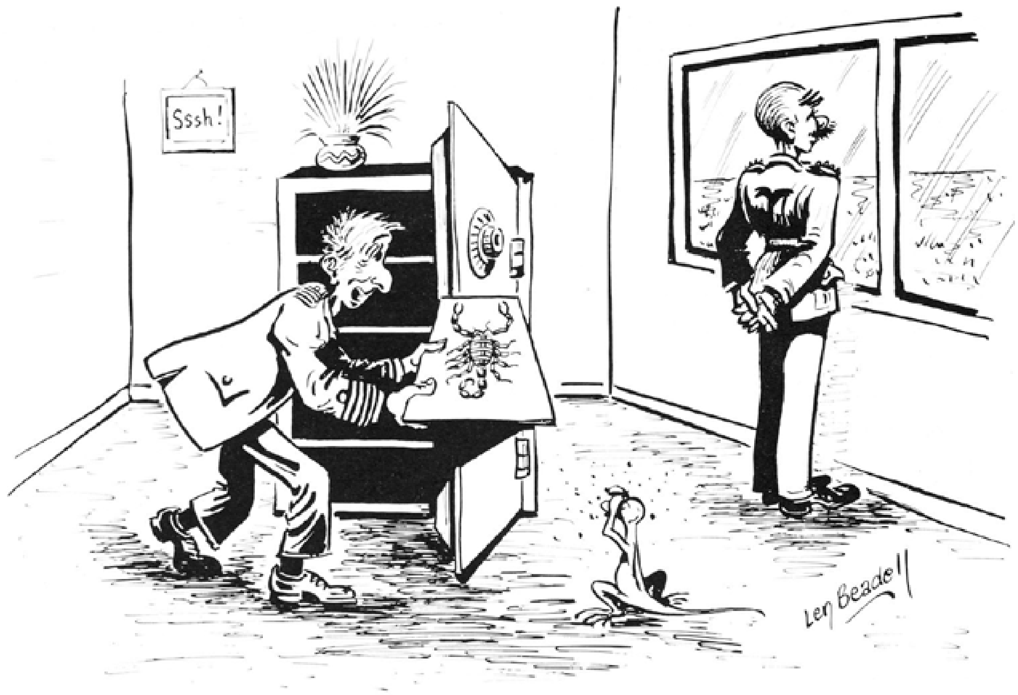
A good deal of the man is revealed in this absurd incident. He had plenty of salty humour and was fond enough of amusement in the right place. No one could call Captain Jack a prig or a puritan—he was a great partying man. In his job, though, he was something of a martinet; strong on discipline and keen, obdurately keen, on keeping the good name of Woomera and the services. His closing judgment on the perpetrator of the pyjama incident surely suggests a man who thought more with his heart than his head. The Navy has always taken more of an interest in its men's private lives than the other services. Newman was married but his wife refused to live at Woomera, so he used to pump a woman friend for information, something she disliked:

> He used to ask me my opinion about various wives. That was very important to Jack because he used to say they could make or break a husband's career. I thought being asked was awful impertinence and whether I liked them or not I'd always answer, 'She's fine'. If trouble sprang up later, which not infrequently it did, he'd say to me, 'Bitch, you lied over that girl!' I think you had to be strong to run a place like that; you had to be frightfully strong. I think probably Newman ran the place better than most because he behaved as though he were standing on the brig shouting '30 lashes!'[36]

Newman's authority was felt in the village, of course; not out at the Range. Like most Superintendents he thought it politic to concern himself as little as possible with the actual work of the Range. His successor in the post, Brigadier Dick Durance, recalls:

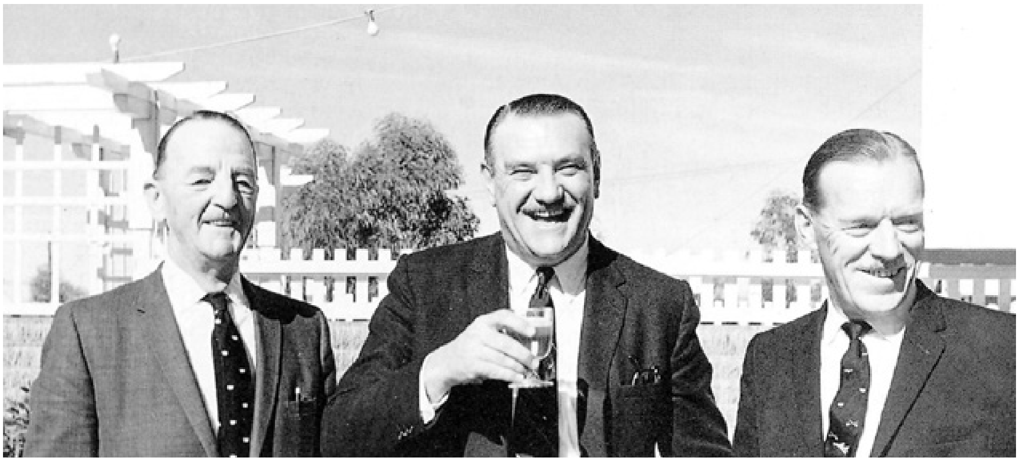
> When he handed over the Tech Area to me, Jack Newman took me into his office and in the corner was a huge safe with a combination lock on the front. Very impressively he said, 'Now, here I must deal with one of my last tasks as the outgoing Superintendent. It is time for me to hand over to you the secrets of Woomera. On this paper is a set of instructions for resetting the combination of the safe. As soon as I've gone you should unlock it and choose a new setting known only to yourself.' I said rather nervously, 'Well, perhaps we'd better have a trial run.' 'All right, then. Do forgive me just a moment.' And he put his stomach in front of it while I politely looked out of the window. He dialled and clicked and turned and then there was a grinding noise as the door came open. I looked into the safe and inside was one sheet of blotting paper with a dead scorpion on it. 'There you have it', he said. 'I put that scorpion there three years ago, and as far as I'm concerned, Dick, that's it. I don't want to know any of their secrets.' I said, 'I don't want to know any of them either, Jack.' 'Well, then, all you have to do is lift that scorpion up on to the top shelf, as a sort of guardian, then every night fling your books in and slam the door. Treat him tenderly.' I did just that, and when I left I handed over the scorpion and the safe to Glen Cooper with pride. Nothing else.[37]

Not that the Woomera Board was itself lacking in characters who could act when occasion required as champions of the people. The best known of these, and the man most



deserving of the title 'Mayor of Woomera' was Michael Breen, the first secretary and founder editor of the weekly paper Gibber Gabber, whose first roneoed issues he produced single-handed. Much older than the average resident, Breen was a big genial Irishman with a powerful brogue and an obvious toupee; a man with all the charm and ready wit of his race, whose compliments cut a swathe through the Woomera ladies though he was a confirmed bachelor who in his younger days had trained for the priesthood. Breen was an unassuming man, but he insisted that the Board should present a dignified image: he battled to get a pleasant air-conditioned office in the village, properly carpeted and with good furniture. Nevertheless, Breen was very aware that the Board's real power to take decisions and make them stick was at best limited. The retrospective view of one of its most able chairmen is that, 'the Board never had any power. It was given power on paper, but it never had any real power.'[38] This judgment relates to the 1950s, and even at that time the elected Board members were prone to gloomy fits of introspection about what use they really were. They were, after all, volunteers. For all the time and energy they put into their honorary posts the results seemed meagre, and sometimes the Board's recommendations were quite ignored. Since four members were appointed, their views were likely to conform with departmental policy, 'people say there are four already appointed, so what is the use in electing three'.[39] Sometimes the Board was convulsed by internal squabbling over matters which only its

Michael Breen, first secretary of the Woomera Board.



Three successive Range Superintendents, Newman (*left*), Durance and Cooper (*right*), at the 1962 Senior Mess birthday celebrations.

members took seriously. On one occasion a newly elected chairman, J. J. Malone, announced summarily that he intended to open each meeting by reading a short prayer. Malone apparently believed that informality in the meetings had been carried too far; the prayer was an attempt to introduce more dignity and solemnity to its deliberations. At the next meeting three of the members remained outside the boardroom and half-way through the prayer the deputy chairman, flushed with anger, got up noisily and walked out. The issue was not the prayer itself—an invocation innocuous to the point of vacuity—but whether the constitution allowed such a thing to be introduced without consultation. Many villagers viewed derisively such issues as these, and they served only to weaken the Board's prestige.

Much of the Board's work was routine. It looked after the franchises, examined applications for visitors to come and stay and dealt with all the minutiae of running a closed and often critical community. But in the eyes of the residents one of its jobs loomed much larger than any of the others: its distribution of all the profits received from operating the village facilities. Until nearly the end of the project, the funds administered by the Board came mostly from the profits of the store, with other small incomes from the swimming pools, community hall and, after it was built, the theatre. The amounts involved were quite large. The town grew quickly; wages were high and disposable incomes were high too. Many families were young with big shopping bills, and despite the endless complaints about the store—discussed on a later page—they spent a lot of their money there. The profits rolled into the Board's coffers and dutifully rolled out again on the authority of WERC (the Woomera Entertainment and Recreation Committee, constituted in 1954 when it had been already been operating for some years, and made up of representatives of affiliated sporting and cultural clubs). Grants and subsidies were generously forthcoming, and if any group wanted anything for which a reasonable case could be made it was natural to turn to the cornucopia of the Board. Good entertainers were brought to the theatre where the ticket prices were heavily subsidised, and every year a big Christmas party was thrown for all the village children, with gifts, sweets, films and the setpiece of Father Christmas descending in a helicopter. Of course, there were a few sceptics who liked to contrast this munificence with the political impotence of the Board, seeing it as no more than a bread and circuses ploy by the authorities to keep the populace quiet and happy. Others thought the money should be disbursed with a little more discretion, pointing out that a small group of enthusiasts might get excited about some minor hobby and receive a grant, only to disband after a couple of years as they were posted elsewhere. Generally speaking, however, the Board was regarded as something of a benevolent father figure by the residents throughout the years of Woomera's prosperity. It was not until the last decade of the project that the cornucopia began to fail. As the population declined and aged, the store's profits dwindled to nothing and then became a substantial loss. The Board began to be starved of funds in 1971, when it cut capital spending to nothing. Father Christmas was made one of the first casualties, the Board's image changed overnight from Pickwick to Scrooge,[40] and many people said

Below left: Because snow and reindeer were lacking at Woomera, Father Christmas always arrived by helicopter.

Below: Handing out the presents at the 1957 Christmas party for children.

bitter things about it even though it was not responsible for the plight it found itself in. By 1976 it was in such a parlous state that it protested when the store management wanted to introduce quarterly instead of monthly payments, and the following year the Board was driven to looking at whether poker machines could be introduced to the village. Nothing came of this, and the residents were spared the experience of having the Scout troop financed by one-armed bandits. When the project ended and Woomera took up its role as support centre for the Nurrungar base, a new financial arrangement between the Department of Defence and the USAF supplied all the Board's funds apart from the profits of the ELDO bar. With two governments now tightly in control of the purse strings, the villagers have had to learn to live at a much reduced level of expectation.

CLUBS, SOCIETIES AND THE CHURCHES

The best index of general contentment with Woomera life was the Board's much appreciated organisation of the residents' leisure. Woomera folk were great joiners, and sports and hobbies clubs existed almost as soon as anything was there at all. Organised sports of all kinds were enormously popular, and for many people playing them and taking part in the social functions connected with them were more important than the mess life. Whatever your sport, indoor or outdoor, the chances were that a club existed or could be created and equipped by the Woomera Entertainment and Recreation Committee (later Institute) at no direct cost to members. The job of WERC was to decide how funds should be disbursed to the clubs in order to meet the cost of such things as equipment, youth activities, visiting instructors, and visits by entertainers and sporting stars. All the clubs' financial statements were scrutinised by WERC and if a club was dissolved through lack of members its funds reverted to a Board Trust Account and its equipment was stored. With this sort of encouragement the clubs flourished mightily: in the peak year 1968 no fewer than eighty-two were active. There were four senior Rules teams, a soccer team, two Olympic swimming pools, tennis, squash, basketball and softball courts, a golf course with sand fairways and oiled 'greens' and an excellent bowling green (whose clubhouses made a democratic alternative to the messes), large bore, small bore, pistol and archery ranges, a go-kart track and stock car racing circuit. There were six ovals, both red clay and grass. At one time even a sailing club operated on the temporarily filled Lake Koolymilka (and a man drowned in it during a lunch time swim). There was an Arts and Drama group with its small theatre in Killara Hall, a choral society, and photographic, amateur radio and astronomical clubs. Apart from the messes the centre of public entertainment was for many years the community hail (previously a RAAF gymnasium in Port Pirie) brought to Woomera in August 1949 as one of its first public buildings. Films were screened there three or four nights a week, and live shows were put on from time to time. It had manifold other uses and was seldom empty. It served as town hall for political meetings and naturalisation ceremonies. Many a club dance was held on its polished floor, and committee meetings in its side rooms. One summer

Right: A practice kick at the Newman Oval.

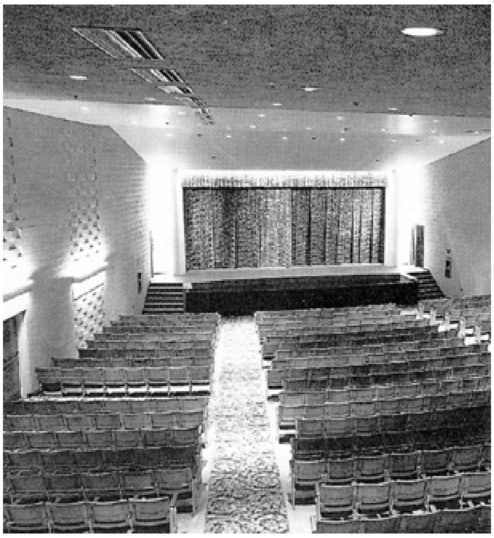
Far right: The two Olympicsized swimming pools were popular in the summer.

late in the 1960s, by this time decayed and something of an eyesore, it was burnt down by children; the fire-fighting force being rendered impotent, so it is said, because they had parked their truck over the hydrant and didn't find it in time.[41] The expensive 'new' theatre was designed to be something of a showpiece, with seats for 700 and excellent stage and projection equipment.

It may be improper to classify religious observance as a leisure activity, but then Woomera was not a particularly religious community. The separation of church and state could never have been a workable concept at Woomera. No minister could have been supported by his parishioners. All three chaplains began by being commissioned officers of the Army or Air Force, and even when this was no longer so their stipends continued to be paid by the project. In the Census of 1961, 37 per cent of the residents gave their religion as Church of England and 25 per cent as Catholic. The major nonconformist sects like the Methodists made up most of the remnant: thirty-four people belonged to the Salvation Army and just three were Jews. Only 12 per cent of the population either professed no religion or did not answer this question. However, it is certain, as social research has shown elsewhere, that the answer to such a formal question bore little relation to the actual piety of the community: it probably only registered what denomination people were raised in. The truth is that regular church attendance was thin. Indeed, the fine United Protestant Church went through such a lean, period that one woman (herself an agnostic) went along through sheer embarrassment to help swell the numbers. The churches filled a very active role at Woomera, but the role they played was more social and pastoral than doctrinal. As in most small communities women in particular were great pillars of the churches, which played the same part in their lives as the messes did in their menfolk's.

Padre Stewart Calder in 1951.

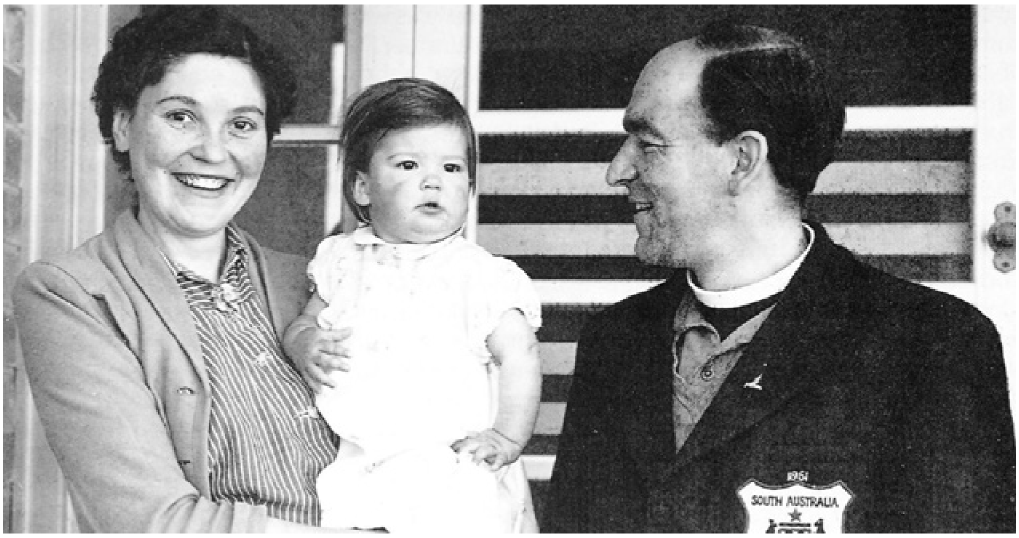
Woomera did not want for spiritual ministration even in the very earliest days. One of the first on the site was a Salvation Army officer, Captain Harry Collins, who walked up to the Phillip Ponds camp from Pimba, where he was working among the railway gangs. Next on the scene was Padre Stewart Calder, who arrived as chaplain to the No. 2 Airfield Construction Squadron and stayed for fourteen years. Calder quickly became a Woomera identity. His particular brand of nonconformist piety grated on some nerves, and he had a blunt way of talking to his parishioners that some of them did not like much, but to others he was something of a hero. Dr Greg Markey, not a member of his congregation, recalls, 'Whenever he knew any of his parishioners were in trouble, with medical problems or maybe psychiatric problems, old Stewie would be there putting his back into it. I had a lot of time for him, though a lot of people didn't. He was also very keen on the sports side of things. He couldn't play because of his leg but he was always organising people.'[42] Calder opened the first church hall, the Protestant Denominational Hall, in September 1949. Later on, in June 1951, the sum of £21 000 was made available to build a proper church, and Calder was determined to build something substantial. He commissioned a distinguished Adelaide architect, K. Murray Forster, who produced a very traditional design in masonry. Nothing daunted Calder and his parishioners spent three months in 1953 carting gibbers and reddish sandstone from old sheep pen walls. Eventually they gathered hundreds of cubic metres of stone for the thick walls and massive belltower. Though the site was prepared with bulldozers



Far left: Sailing on Lake Koolymilka, but only when it was full.

Left: Interior of the 700-seat theatre.

Anglican Padre Howell Witt and family in 1951.



borrowed from the RAAF, most of the building was done by hand, including raising the tall concrete window frames into place. Several points were stretched to the limit when it came to finding the other building materials. One day Calder came to Bouch, the Project Officer, and asked casually if he could take some sheets of iron which he had noticed on the Department of Works scrapheap. Bouch agreed to this innocent request, only to discover later that what had been 'found' among the scrap were two crates of perfectly good roofing iron. Somehow Calder got away with it; Bouch thought he must enjoy divine protection.

The church was consecrated in October 1956, and under the name of the United Protestant Church became the place of worship for most of the Woomera Christians other than the Anglicans and the Catholics. Later it was joined by St Michael's Catholic, a utilitarian building clad in iron with a stone facade, and St Barbara's Anglican, a modernistic building shaped like a Nissen hut. Neither of these churches had a long life. St Michael's eventually burnt down and was not replaced, and St Barbara's became the town museum.

Apart from Calder, two of the early padres who made a lasting impression were the Anglican Minister Howell Witt and the Catholic Father Paddy Molloy. Witt was a cultivated and witty Welshman whose autobiography Bush Bishop gives an entertaining account of his outback experiences. Father Molloy was a different type: an austere and shy man who did good by stealth. There is one anecdote about him that captures his qualities admirably. One day during a routine flight from Woomera conditions were very bumpy and a young Computer grew nauseous. She managed to keep from vomiting in the crowded, noisy and fume laden Bristol right through the trip but as the plane came jolting in to land she could not last any longer. Her plight became urgent, and there was no sick bag. Seeing her distress, Father Molloy, who had his Army greatcoat over his knees, held out its bottom edge to form an impromptu bucket and the poor girl was violently sick into it. As the passengers disembarked, Fr Molloy calmly folded up his coat into a neat bundle and strolled away without a word.

Whatever its shortcomings life at Woomera had a rich texture for a community of its size. Surely only the most churlish, the most anti-social, could complain of being isolated and bored? Few of the ex-residents recall any such feelings. If they admit to any disadvantages, they mention the smaller irritations and natural rigours: the dust storms, oppressive heat and lack of scenery; the petty constraints of security; the poor transport services; and above all else the deficiencies of the village store. For if a time machine were to let off a social analyst on a Woomera street corner in 1950, 1960, 1970 and even 1980, he would find his interviewees agreeing across three decades that the shopping in Woomera was terrible, always had been, and 'they' didn't care.

THE SAGA OF THE WOOMERA STORE

Of all the institutions of Woomera, the store (originally the 'community store' and always the only shop of consequence in the village) attracted the most odium throughout the project years. Its failings forced themselves on the attention of those blind to the other deficiencies of life in a closed town, for no one could dispense with its services. It was a natural focus of discontent, an Aunt Sally which provided a convenient symbol for 'them': 'them' being the administration, the Department, the government in general or indeed any of the officials who at one time or another exasperated even the most phlegmatic resident. Perhaps its stock and services were sometimes unreasonably criticised, but its usefulness certainly never approached those apparently chaotic general stores in little towns where the owner can lay his hand on almost anything. The store management had a way of plunging its unwary customers into scenes straight out of Heller's *Catch-22*. One recalls, 'I went to the store to buy fittings for a tap but none of the fittings in stock were the local size. I complained about it, but the chap said that they were not allowed to order anything until the stocks were exhausted. Naturally they never were going to be used up, being all; the wrong size!' Such anecdotes vividly suggest how ill equipped any bureaucracy is to respond flexibly to consumer needs. And, of course, the trouble was exacerbated by most of Woomera's people being urban exiles used to urban shopping. The woman who wanted to buy a modish new dress on impulse was never likely to take pleasure in the store, whoever was managing it.

Of course, this was not the only perception. A few stalwarts thought one of Woomera's positive points was that it had almost no shops to waste time in:

> They had everything really: certainly olives or bits and pieces like that you could get. I recall my son, aged three at the time, loved asparagus and I once found a tin of it clutched in his hand when I left the store. So they certainly stocked asparagus. And you could always write down to David Jones for exotic things. I just can't understand people grizzling because they couldn't get *White Wings Cake* Mix or some such.[43]

But this was an extreme minority opinion. Much more common were the views of one ex-resident who said feelingly that after a couple of years of grappling with the store he was able for the first time to appreciate the full horror of life in a centrally planned economy. In trying to find out why, for the third year running, the store was not stocking children's sandals in the middle of January, he often felt sympathy for the poor Muscovite wandering past the uninviting shelves of GUM, the pretentious department store in the Soviet capital.

The failure of the store over many years to meet its customers' needs is the more pointed in that it was founded with the very best of intentions. For in the abstract the idea of a community store was an admirable one. Here was a tiny isolated township which could not possibly support more than a few shops. If private enterprise in the shape of one of the large chains was invited to set up in business, it would have little competition. Effectively it would be a monopoly supplier. This was an unattractive prospect. Why not keep the capitalists out by establishing a community enterprise, with the prices set at Adelaide levels plus freight so that the profits instead of being 'exported' could give the Board an income which it could administer and return to the community for the general good? There were plenty of models for such an arrangement. Something of the sort was working well at Inyokern in California. The Victoria Barracks canteen in Melbourne was run by a committee. And there were success stories close to hand too: at Nuriootpa in the Barossa Valley a community store had worked for some years, and was combined with a profitable hotel also owned by the town. Surely the people of Woomera would be no less efficient at operating their store? Later on when it was running smoothly perhaps they could add an hotel, cafe and cinema, with the profits from them all being ploughed back into the village. For this reason any kind of private business was long resisted, except for two garages, a chemist, a hairdresser and various specialised franchises for hat making, dog catching, taxi driving and so forth.

The number of resident families was already moving up to the 200 mark when, in November 1950, the proposal was first mooted 'to set up a Store to meet the needs of the general community with a large range of foods, including clothing, footwear, stationery, general hardware, groceries, vegetables and general household goods.' The village Board asked for £8000 from the Department of Supply to found and stock it, and it opened its doors in February 1951, in a temporary building called Hut 39. At first the store was regarded with some suspicion as a socialistic enterprise by local suppliers, one of whom wrote to LRWE to check .whether it was financially sound. Once over these teething troubles it was reasonably

Woomera's first 'community store' in Hut 39, 1952.

successful, producing a net profit of £1273 in its first six months of trading. It stocked only the quickest moving lines: groceries and greengroceries, some clothes, smallgoods, newspapers, petrol from a bowser outside and oil. Attached to it were a bakery, a butcher's shop and a soft drink plant.

The new store building which today forms the northern side of Butement Square was completed at the end of 1953, with ten sections offering everything from groceries to drapery. It was incorporated but free from taxation under the Companies Act. The memorandum of association drawn up at the time was a magnificently inclusive document which covered almost every conceivable area of trade which the store might want to move into: drapery, furnishing and outfitting, dairying, fruit and vegetables, butchery (including slaughtering, dressing and preparing cuts), bakery in all its branches, refreshment room proprietors, chemist and druggist, ice merchant, general laundry and dry cleaning, electricians and dealers in all sorts of electrical apparatus, wholesale and retail jewellers, silversmiths and optical and scientific instruments, the management of theatres, concert halls and cinema shows, lithography, engraving, publishing, printing, newsagency, hotel keeper, wines and spirits merchant and 'garbage proprietor'. The profits were to be expended as the Company thought fit on establishing and supporting sport and recreational facilities, gardens and reserves, pools, gyms, libraries and reading rooms, picture galleries, museums, creche welfare and health clinics, clubs, exhibitions, billiard halls, theatres, cinemas and music halls. It really was to be 'Woomera Inc.', though a curious detail of this arrangement did not emerge until 1964, when Treasury lawyers advised the Department of Supply that the store profits were properly 'public moneys' and that for the last decade the Board had been getting its income illegally.

Early in 1954 the store was at the centre of a divisive issue which raised passions on all sides. Still operating in Woomera at this time was the Army Canteens Service (AACS), an organisation which had supplied the very first Forces construction teams and Department of Works men with their food and drink. For the Canteens Service Woomera was a profitable operation because it, unlike the store, sold liquor. Now it formally proposed taking over control of the store, for the ostensible reason that it had to meet its obligations to servicemen. In no quarter was the response to this proposal any better than tepid. The Range Superintendent of the day, Group Captain Pither, thought that ideally the store management should be left in the hands of the community, but he recognised this was the counsel of perfection. 'It seems imperative', he wrote privately, 'that either Army Canteens leave Woomera completely or run the whole show; and as Department of Supply does not seem able to determine this issue, I consider it has no alternative but to give way to Army Canteens.'[44] At Salisbury the Chief Superintendent was no happier about it. C. F. Bareford found the proposal nebulous about terms and conditions, and he thought it especially absurd that the control of a central Woomera institution should be lodged in Melbourne. As for the Woomera Board, its secretary Michael Breen noted acutely that nowhere in the proposal did Canteens guarantee to sell at Adelaide prices or, worse, to return so much as a penny piece of the profits to Woomera.

The present store location in Butement Square. In the foreground is the war memorial, and at left the coffee lounge and ill-fated Mirage restaurant.

Nevertheless, other important factors weighed on the other side of the scales and eventually tipped the balance in favour of AACS. The chief one was that things were not going too well with the store. Though it was not unprofitable—it had already returned around £10 000 in profits—in many eyes the manager was incompetent and the butcher shop a disgrace. The meat was so poor and expensive that many customers preferred to order theirs from Whyalla, whence 500 kilograms were arriving each week by airfreight. Indeed, the situation had deteriorated so far that the Department of Supply had had to step in and create a special board of directors, so that instead of being a community effort run by and for the people the store had somehow been turned into a cog of the departmental machine. But the responsibility of running a big shop weighed heavily on the voluntary directors at Woomera, few of whom had had any commercial experience. Whatever the shortcomings of Canteens (and hardly anyone thought much of its performance so far) at least it was experienced in victualling troops all over Australia, and the temptation to shift the load on to more experienced shoulders could not be resisted. Thus it came about that after a stormy meeting lasting four hours, the Board voted to hand over the store.

Some weeks later news broke confirming Breen's worst fears. Though Canteens was still insisting on being the sole trader in town, it now openly conceded that all the envisaged profits, optimistically assessed at some £50 000 a year, would be going straight out of Woomera. As soon as it got wind of this, the Board, at its next meeting on 26 October 1954 furiously rescinded its previous motion, voting instead that the existing arrangements be adhered to. But it was too late. The recommendation was ignored. Somehow a better deal was hammered out, whereby Canteens was to be paid a management fee (a percentage of turnover) with the remaining profits passed to the Board as before. By the end of July 1955 Canteens had all trading in the village in its hands, including bread, milk and the butcher shop. It retained all the staff except the manager and the accountant, both of whom were dismissed. From then on to the end of the joint project AACS, and its later incarnations ASCO and AFCANS, were in sole charge. Many a time its officers must have reflected that their organisation had never made a worse acquisition.

In a hopeful letter to WRE formally acquainting it of the takeover, Chief Scientist Butement anxiously expressed the wish that Canteens be given a fair go: 'whilst residents should not withhold justifiable and constructive criticism, they should also be co-operative'.[45] His hope proved vain, especially at first. Some of the innovations were liked, such as the lockup newsagency, the milk bar and some weekend trading. But these were quite overshadowed by a storm of complaints over Canteens' lucrative new policy of selling liquor over the counter. The staff had been well briefed on the perils of selling drink to 'children, to coloured people and to intoxicated persons,' but tiny tots choosing their lollies were now being jostled aside by crowds of thirsty men eager to get at the beer crates in the self service grocery department. A visitor was amazed to see two children, the elder no more than nine, pushing home a pram sagging down on its springs under the weight of bottles. After one alcoholic had died in the hospital his wretched cubicle at the Jazza was found to contain no fewer than 32 empty flagons.[46] In a strongly worded memo to the Superintendent entitled 'village morale', Breen, spokesman as ever for village opinion, did not mince words. The cost of living had shot up, as a direct result of the store's new prices: one family was saving eight shillings a week by buying its meat in Whyalla. Dissatisfaction was intense and universal:

> The absence of an alternative supply of groceries, foodstuffs and household requirements has engendered a sense of futility and desperation. This is further intensified by the impersonality of the service, the absence of any real attempt to supply the individual needs of housewives and the provocative attitude of those who control the Store. Surely a sympathetic attempt at ordinary courtesy to the housewives and their requirements would, at least, act as a damper on inflamed feelings.[47]

Eventually AACS gave way and stopped selling alcohol, but not before a well publicised incident when a drunken shearer with some grievance burst into a nearby homestead and menaced the family with a loaded revolver. It emerged at his trial that he had been able to get all the drink he wanted, no questions asked, over the counter at Woomera.

Still, whether because of Canteens' management or despite it, the store proved profitable enough for many years.[48] Throughout these years its reputation see-sawed alarmingly, and no doubt these oscillations were the index of deeper waxing and wanings in the level of contentment with Woomera life. In March 1957 the local branch of the Country Women's Association wrote to the Board saying unequivocally that 'complaints from members and others are so numerous that to itemise them would be impossible. The whole Store is completely unsatisfactory.'[49] Murmurs were again heard against the virtual monopoly enjoyed by Canteens, and the complaints this time went to the local MP and thence to Minister for Supply, Howard Beale, who would not admit that anything was amiss. The store, he said, was providing a service available to few country towns, and the variety, availability and prices were very good. But not many customers shared this rosy view, especially those who joined the regular exodus down to Pimba to meet the Tea and Sugar train, which supplied the railwaymen along the transcontinental line. Forty cars or more could be seen parked there, and the train butcher was serving continuously for five or six hours at a time. Yet things did improve over the following year thanks to the labours of an excellent new manager, G. C. Gourlay, who tried the radical approach of listening to the complaints and then actually doing something about them. In March 1958 the Store Advisory Committee carried a unanimous vote of thanks for the work he had done. Even Jack Newman, not one to offer praise lightly, commented on 'the ability of Mr Gourlay and the remarkable change he has brought about in the store's relationship with the people of Woomera'. But down went the see-saw again: a few months later at the end of the year the Board was recording in exasperation that 'the patience of the citizens of Woomera is completely exhausted with the service provided'.[50] This time AACS had a full inquiry and put their own representative into the town, a major who agitated himself in the summer of 1959 over the 'unnecessary' sight of women buying their groceries in bathers.

One perennial irritation was that the messes were obliged to obtain their supplies through the store too, and at what were universally held to be elevated prices. In September 1956 Jack Newman reported poker faced to Salisbury that he had discovered a heinous breach of the regulations. While he was away one of his staff had surreptitiously arranged for two tonnes of potatoes, destined for the mess kitchens, to be loaded in Adelaide on to an empty government truck bound for Woomera:

> His only excuse was that the price was £90 per ton less than that charged by the Army Canteens Service, and the net saving to the Department was approximately £165. No disciplinary action has yet been taken.[51]

Whether Salisbury appreciated this barb is not recorded.

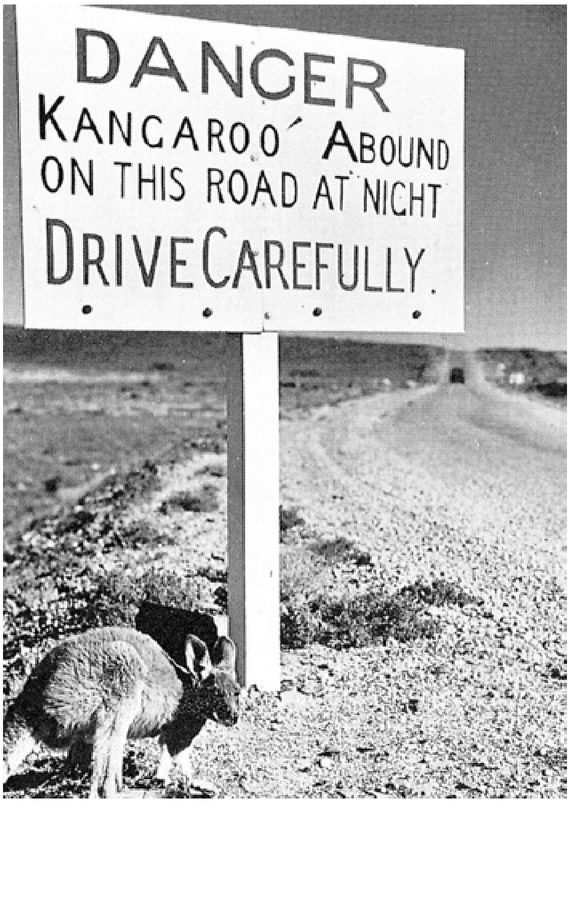
Certainly ASCO was not wholly to blame for a state of affairs which lasted right through the 1960s and beyond. ASCO, of course, had charge of the stock and the service. But the woebegone appearance of the store by the early 1970s, the peeling and faded paintwork, the tatty, old-fashioned fittings and the corroded leaking pipes in the cold rooms could be laid at the door of the Department of Supply. The managing director of ASCO had a point when he said bitterly that his organisation had paid in rent not much less than a million dollars to the Department over the years, and precious little of it had been returned in improvements or even basic maintenance. All the more galling was the sight of private enterprise reaping its reward down at Pimba, where the energetic 'Spud' Murphy was running a bustling shop and restaurant and had plans for a motel. The Area Administrator asked Salisbury 'what would be the Departmental situation if Tom the Cheap set up in the Pimba area independently or as an extension of Mr Murphy's shop? It is apparent that, due to lack of business acumen, ASCO cannot compete with the outside cash order stores.'[52] But no solution sprang to mind except for the mean though fleeting proposal that the Pimba folk, hitherto given passes to the village for recreation and entertainment and shopping, might be deprived of them in retaliation for taking their patronage away from the store. Nor did the problems end with the joint project; if anything they were worse, for by this time even the profits had turned into losses. In March 1982 the Area Administrator was commenting despairingly 'there is little sign of enterprise or any attempt to present merchandise attractively, and a complete lack of professionalism . . . At almost every point, it seems that store management displays a serious lack of competence, drive and customer orientation.'[53] Much the same words could have been, and in fact were, written twenty-five years earlier. It is a story of remarkable though hardly praiseworthy consistency, which is little to the credit of those who had brought the social organism of Woomera into existence for their own purposes and therefore had responsibility for its welfare.

IN AND OUT OF WOOMERA

Far behind the store as a pet dislike came the transport services. Even those who loved the self-contained life of the town felt the need to escape from it sometimes, if only at 'stand-down', a break of a month (later five weeks) in December and January when the Range closed. But leaving Woomera, and getting back there, could be a tiresome business. The road and rail connections to Adelaide each took eight or nine hours, and neither trip was a very pleasant experience. To travel by car meant negotiating the notorious 180 kilometres of sandy, roughly graded track to Port Augusta. Gibbers, potholes and kangaroos made the route treacherous at any time, and after the heavy rains which fell a few times a year had turned the bull dust into mud the road was impassable for days. Despite constant protests, 150 kilometres of unsealed Stuart Highway lasted practically to the end of the project and through all its busiest years; ironically, it was not entirely sealed until 1983, long after the most urgent need had passed. Squabbles over who was to pay for it had lasted three decades and no one could count the cost in frustration, wasted time, vehicle

Below left: An appropriate warning sign on the road to Koolymilka.

Below: The Budd railcar arrives.



An Airlines of South Australia Convair aircraft arrives at Woomera in 1970. Fokker Friendships were used later.

damage and maintenance. Even more punishing, of course, were the other tracks around Woomera. In the winter of 1952, with four vehicles a day receiving major overhauls, the Transport Workshops were one of the busiest facilities of Woomera. As for the train journey, after April 1951 travellers could use a Budd railcar operating between Pimba and the Port Pirie junction. These were American, diesel and air-conditioned, though their modernity was difficult to appreciate when the Adelaide bound connecting train departed at the anti-social hour of 3.40 a.m. Eventually the Budd became uneconomic and ceased to run, and instead Woomera was allocated six seats per day on the Transcontinental trains, with no guarantee of getting a meal on board. Small wonder that most residents preferred to use the air service, particularly if there was any degree of urgency. As described earlier, the common mode of transport to and from Adelaide in the earliest days was a RAAF Dakota or Bristol Freighter out of Mallala. In 1950 a much better commercial service became available: TAA's new Adelaide-Darwin-Adelaide routing, which brought a DC-3 to Woomera twice a week with its comforts of real seats and hostess service. Ultimate luxury was provided from 1955 with the provision of a charter service operated originally by Guinea Airways—later Airlines of South Australia (an Ansett company)—which provided a Woomera-Adelaide service eventually using Fokker Friendships until it ended with the run-down in April 1979. In the early sixties there was a plane each morning and afternoon, and seats were always free for travel to Adelaide on Monday and back on Friday afternoon. The pioneers a decade earlier rated a free shopping trip to Adelaide every three months. After one such trip close to Christmas the shoppers landed to find all their presents had been left on the tarmac at Adelaide Airport. A Lincoln bomber had to go down to recover them.

As this episode suggests, things were not really so bad. The wife who had lived in a Sumatran oil town where it took a month to get an exit permit or who had sweated it out in a jungle RAAF camp in New Guinea found the open spaces and amenities of Woomera delightful, and perhaps she can be excused for wondering what the grievances really amounted to. Was it not possible to counter the isolation by joining record and book clubs? Didn't the excellent country service of the South Australian Library exist solely to send its members vast parcels of books by train?

> I've lived in the country all my life and the first thing I did in a new place was to join the library. To me it was extraordinary: they'd grizzle, all these people, but they used to borrow books from me by the armful. You didn't have to go without all these things if you just went to a little bit of trouble, but they wouldn't be bothered.[54]

Such a stout-hearted woman, if pressed, would probably resort to the platitude that life in Woomera was what you made it; and this like most platitudes hardly admits of an answer.

Notes and Sources

1. L. Ivan Southall's simile, in *Woomera*, Angus & Robertson, Melbourne, 1962, p.77.
2. R. H. Patterson, *The Climate, Soils, Plant Ecology, Agricultural Activities and Vegetative Development—Woomera Research Project Areas, North West Arid Interior, South Australia*, Department of Supply, Melbourne, 1959.
3. Anecdote of Peg Bell, widow of Range Overseer Squadron Leader Colin Bell, in an interview of 5 October 1983.
4. Reminiscence of Roma Birkill in an interview of 20 May 1983. In fact swimming could be enjoyed in the temporary lakes for the first year or so, and Woomera's first Christmas party was held at Lake Richardson. Perhaps such occasions were fairly riotous, for an early Minute sternly forbids skinny-dipping in mixed company. In November 1949 the Range Superintendent optimistically put in a requisition for a small pier and floating pontoon to be installed at Richardson. He expected, he said, that the lake would soon become 'the Glenelg of Woomera.' (Glenelg is the old and popular coastal suburb of Adelaide.)
5. An anecdote told by Haydn Evans, now of TTS Division, AEL.
6. No other significant information has come to light on the planning of the village before the Interdepartmental Committee meetings of May 1948, though obviously there must have been some.
7. Report of Chief Executive Officer of 16 December 1947. AAMP 1728, file GW/W/10.
8. Some idea of the cost of founding Woomera may be gained from the fact that in the monetary values of the mid-1980s the houses mentioned here cost from $70 000 to $150 500 each.
9. Information on Woomera gardening practices from Mrs Dulcie lay (contribution of 11 October 1983) and Mrs Peg Bell. One measure of the keenness of the Woomera gardeners is the number of trees and shrubs issued by the Arboretum. In 1968, 4076 plants were issued to 244 houses, an average of 16 per house. One house took 74 plants! Unfortunately, to save costs, no records were maintained after 1970.
10. Reminiscence of Bob Mitchell, late manager of the Woomera store, in an interview of 20 May 1983.
11. From a contribution by Mrs Pauline Windeyer (formerly Tilden) of 29 August 1983. She lived in Woomera from 1962 to 1977.
12. Interviewed at the Woomera residents' reunion on 1 May 1983.
13. Report dated 23 June 1972 from DCW Probation Officer T. Bickerton. She also pointed to the boredom and amotivation among older children, the high rate of under age drinking and the chronic alcoholism, though she could not say definitely that more problems existed than in the average rural town of its size. The Area Administrator largely discounted the report, saying there was 'not much substance in the criticism of the Woomera way of life, the "problems" being based on many inaccuracies.' File A 14/4/5.
14. Undated contribution by G. E. Hicks.
15. Reminiscence of Irene Barber at the reunion interviews of 1 May 1983.
16. A point made by Ron Ettridge at the reunion interviews of 1 May 1980.
17. Anecdote of Marian Frost, who lived at Woomera in the early sixties.
18. Anecdote of Dr Greg Markey, MO at Woomera in the fifties, in an interview of 20 May 1983.
19. J. Clark, 'The Woomera experience', *Army Quarterly and Defence Journal*, 107 (July 1977), 356.
20. Mitchell.
21. In 1972, for instance, four young men got drunk one weekend, started a bonfire on open ground and made a nuisance of themselves in the Jazza. Though only fined $10 in court all were sacked and therefore had their residential permits withdrawn. The second case is an anecdote from the Ettridge interview.
22. Mitchell.
23. Reminiscence of Roma Birkill in an interview of 20 May 1983.
24. In mid-November 1953, eighty-two men belonged to the Senior mess: thirty-six servicemen and forty-six civilians. 104 men belonged to the Staff mess: forty-three servicemen and sixty-one civilians. Overall the proportions were 42 per cent servicemen and 58 per cent civilians.
25. Memo dated 8 May 1953 from Range Superintendent to the Chief Superintendent LRWE. File 56/308 part 1.
26. Minute dated 21 October 1954 from the Security Officer to the Range Superintendent. WRE Woomera file 56/305 part 1.
27. Memo dated 14 December 1954 from Director, Posts and Telegraphs to the Chief Superintendent LRWE. The technicians were eventually upgraded. File 56/305 part 1.
28. Minute dated 1 July 1957 from Accountant WRE Woomera. File 56/305.
29. Minute dated 13 January 1955. File 56/305 part L
30. Memo dated 19 August 1954 from Chief Superintendent WRE to the Controller, Research Trials and Services. File 56/305 part 1.
31. In one such case, Tom and Irene Barber spanned the social spectrum: as a driver he was JSC while his wife, a sister in the hospital, was Senior. Reminiscence of the Barbers in an interview

of 1 May 1983.

32. Memo dated 23 July 1974 from the Director WRE to Deputy Director Trials. File 5628/1/15.
33. The adoption at Woomera of some parts of Inyokern's administration is probably the source of the oft-repeated but false story that the village physically copied the plan of the Californian base.
34. Reminiscence of Brigadier R. Durance in an interview of 5 December 1983.
35. Letter dated 14 April 1958. File 773/1/1.
36. Bell.
37. Durance.
38. The judgment is that of John Hotham, late chairman of the Board, in an interview of 13 October 1983.
39. Minutes of the 76th meeting of the Woomera Board on 26 July 1955. File 773/2/2 part 2. Elected members were increased to six in 1962.
40. Derived from notes on the history of the Board by Mrs M. J. Strauts. Some retrenchment was inevitable, but the decay in the facilities hit Woomera hard. The Area Administrator wrote at the time: 'I am very concerned that the attractions of Woomera are being slowly and systematically whittled away. At no time have the conditions of service and extra attractions offered in Woomera ever appeared to equate to those offered by firms such as Mt Isa mines, Hammersley, etc. . . . Standards of performance of duty will drop still further.' Memo dated 12 November 1970 to Chief Administrative Officer WRE. File 5628/4/3 part 1.
41. Mitchell.
42. Markey.
43. Bell.
44. Letter dated 22 February 1954 and marginal notes from the Range Superintendent to the Chief Superintendent LRWE. File 539 part 1.
45. Letter dated 27 June 1955 from Chief Scientist to the Controller WRE. File 539 part 2.
46. Memo dated 19 July 1955 from the Range Superintendent to the Controller WRE. File 539/3.
47. Memo 'Village morale' dated 29 July 1955 from Woomera Board Secretary M. E. Breen to the Range Superintendent.
48. The store profits returned to the Woomera Board for selected years between 1957 and 1980 were:

Fiscal year	Profits($)
1957-58	13 894
1958-59	28 318
1959-60	35 978
1960-61	35 608
1961-62	37 070
1962-63	38 850
1966-67	92 971
1967-68	101 529
1968-69	206 235
1969-70	100 993
1970-71	67 346
1971-72*	118 523
1979-80 (end of project)	72 909

*Nurrungar project begins. These figures take no account of inflation.

49. Letter dated 6 March 1957 from CWA Honorary Secretary P. Pannell to the Board Secretary. File 738/3/1 part 1.
50. Letters dated 26 March 1958 and 1 December 1958 from the Range Superintendent to the Controller WRE. File 738/3/1 parts 2 & 3.
51. Letter dated 21 September 1956 from the Range Superintendent to the Controller WRE. File 738/3/1 part 1.
52. Memo dated 5 March 1971 from the Area Administrator Woomera to the Deputy Director Trials Wing. File 5628/1/1 part 1.
53. From a report of discussions with the Area Administrator and DSCW staff during a visit of 9-11 March 1982. File 5628/1/1 part 1.
54. Bell.

14 Instrumentation 1: *The Eyes of the Range*

PURPOSE OF RANGE INSTRUMENTATION

The Woomera Range has often been called a large outdoor laboratory and this is a fair description, for it existed to carry out experiments (trials) on the flight of guided weapons, research rockets and bombs. Each trial was part of a program to develop a weapon, or to conduct scientific research into fields such as upper atmosphere physics, or to develop the technology of satellite launchers. To carry out its trials the Range needed facilities such as test shops to prepare missiles, launchers from which to fire them, and airfields for manned and pilotless trials aircraft. It also needed a swathe of country and a great block of aerial space in which all this could be done safely. But Woomera was not just a place to drop bombs or fire missiles. It was an experimental range and, just like an indoor laboratory, it had to have suitable instruments to observe, measure and record what was happening during the experiments.

Some of the many instruments installed on the Range were there to ensure that trials were done under carefully controlled conditions, and done safely. Both requirements demanded measurements to be taken in ‘real time’ so that they were instantly available. In the case of an interception trial, for example, a pilotless Jindivik aircraft would be flown from the ground along a given track at a given height and speed. The missile would then be fired to intercept it at a predetermined point. To be successful this required a tracking system to measure constantly the Jindivick’s position, and plotting tables to present the information instantly to the Jindivik control crew at Evetts Field and to the Trials Control Centre at the rangehead, where an automatic countdown would launch the missile at the right moment. While the missile was in flight, surveillance radar and other trackers might be used to follow it and feed its position to plotting tables and impact predictors, so it could be destroyed if it threatened to cross or land outside a safety boundary. The earliest source of real-time tracking data was the short range AA No. 3 Mk 7 radar sets used at Range A for navigating bomber aircraft, which displayed aircraft position on a servo-driven plotting table. A longer range radio Missile Tracking System (MTS) was later installed at Range E until this was displaced by powerful precision FPS-16 and Adour radars.

But obtaining and presenting information instantaneously during a trial was only one job for the Range instrumentation, and not the most important. Woomera’s fundamental purpose was to measure precisely the performance of the missile or other device under test. Real-time information was too evanescent and not accurate enough for this purpose. What was needed were instruments that could record their findings, so that after the trial their film or magnetic tapes could be sent down to Salisbury for further processing. There most were read, either manually or automatically, and the resulting readings computed to give timed measurements of quantities such as trajectory, attitude and the internal and external behaviour of the device under test.

Perhaps the most important of these quantities was trajectory. The prime quantity was position. In virtually all trials one had to know exactly where the missile, or aircraft or bomb was at each instant. Thus the instruments had to produce a record from which its changing position relative to the earth could be located at tiny successive intervals perhaps only a twentieth of a second apart. For many trials one also needed to know velocity and perhaps acceleration; and the records, if they were good enough, were used to derive these quantities mathematically by successive differentiation. Taken together, these three quantities—position, velocity and acceleration—were often called ’trajectory’.

At Woomera several quite different systems were used to measure trajectories. Some of them were designed specially for the job, like the ground speed cameras installed at Range A for 'end-point' bomb ballistics trials, and later the very accurate ballistic cameras that were used only for night trials of high altitude rockets. But the most universally popular instrument for this purpose was the kinetheodolite. Wartime German Askania kinetheodolites were used in the first years, until gradually replaced by ones made by the Swiss company, Contraves. At one stage their popularity was threatened by the doppler system, which promised longer range, automatic data reduction and results in all weathers; but doppler eventually fell out of favour because it could not be made accurate enough. The later precision radars had the same advantages as doppler, and additionally were useful for real-time tracking as well as recording, but even the radars did not supplant the Contraves kinetheodolites which despite some shortcomings remained the major source of trajectory records, particularly when velocity and acceleration were needed.

All these instruments gave the trajectory of the flying object as it appeared from the ground. Another class of instrument was designed to give 'relative trajectory', or the trajectory of one moving object as it would appear to a hypothetical observer on another. The leading case was interception trials, where one needed to know the changing position of the missile relative to the target aircraft so that one could measure the 'miss distance vector', which is the separation distance and angles at closest approach. For any military weapon the ultimate test is how closely it approaches its target. With a few exceptions the anti-aircraft missiles tested at Woomera were not expected actually to collide with the target every time, because in live use they relied on proximity fuzes to explode their warheads at the closest point. While under test the miss distance vector was a measure of how well the missile would have performed in battle, and thus it had to be measured accurately. This was one of the first and trickiest problems that the LRWE instrumentation experts faced. In theory one could use kinetheodolites to plot the position of both missile and target independently and simply take the difference, but in practice the errors were too great because interception usually occurred far away from any instrument on the ground. The eventual solution was to fit rugged recoverable cameras with a very wide field of vision in the target aircraft. Some trials called for the attitude of a missile to be measured in pitch, yaw and roll angles, sometimes relative to the ground and sometimes relative to the target. This was a difficult problem for much the same reasons as for miss distance, and the eventual solution was similar. Special cameras were developed to fit into the missile itself.

Another frequent need was a record of external behaviour, which was a timed film showing the outside appearance of the flying object at launch and how it looked from the ground during flight. Such a film was eagerly sought to help diagnose a problem if the missile misbehaved, and it was also used to measure the time of boost separation, the discharge of grenades, or the warhead burst. Throughout the project one camera type—the Vinten HS300 high speed cine camera—provided virtually all behaviour records. Vintens were set up on a variety of mounts, ranging from simple tripods holding remotely controlled cameras near the launcher to the relatively sophisticated servo tracking mounts needed for long range tracking.

Perhaps the record of most urgent interest after the trial was that which showed what had been going on inside the missile. The functions monitored could be many and various, covering such things as the missile's accelerations and the operation of its guidance, control, power, fuze and warhead systems. For the early RTV1 trials simple rugged 'scratch on celluloid' recorders were fitted in the missile and with luck recovered afterwards, but later they were abandoned in favour of radio telemetry. Here readings from various electrical sensors in the missile were transmitted via a multi-channel radio link to a ground receiving and recording station.

All of these instruments, both real-time and recording, had to be timed, either to synchronise them or to add a time dimension to their records or data. This was done by means of a highly accurate central timing unit: a beating heart whose pulse reached into every capillary of the Range organism.

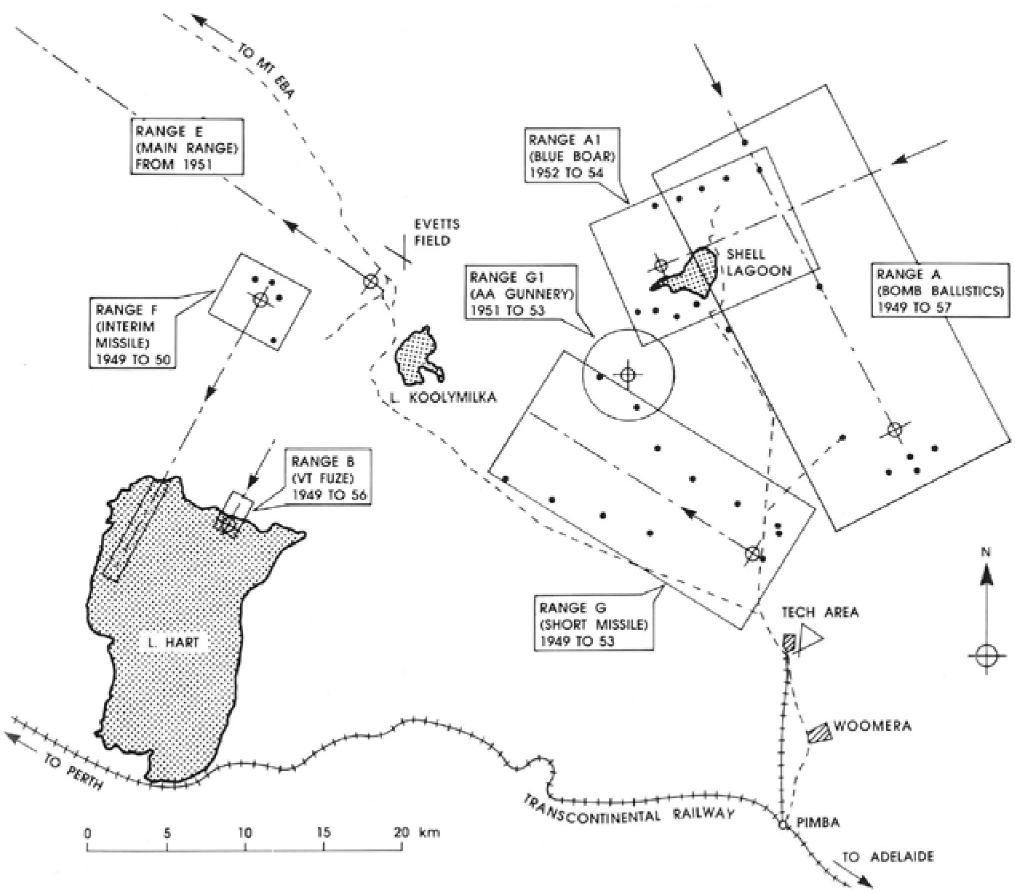
Closely associated with the instrumentation but not strictly part of it were various supporting services: communications, sequence control, firing circuits and an elaborate real-time acquisition system which helped to guide the tracking instruments to the best spot in the sky to pick up the missiles and aircraft in flight. Acquisition data were particularly required by those stations too far down-range to see the launcher.

After the missile had been fired and the target hit or missed, oral reports were taken from the Range operators. But the detailed analysis was yet to come, for the data collected on the films and tapes still had to be transformed into meaningful information for the Range user. Some of this, the telemetry 'instant replays' for instance, was done within a few hours to give the customer a quick look at what had happened. But most of the work was done at Salisbury, where films were processed and the data on the tapes converted into a format compatible with the WRE computer. Finally the records were reduced to meaningful information in terms of trajectory, velocity, acceleration and so on. The whole process is described in a later chapter.

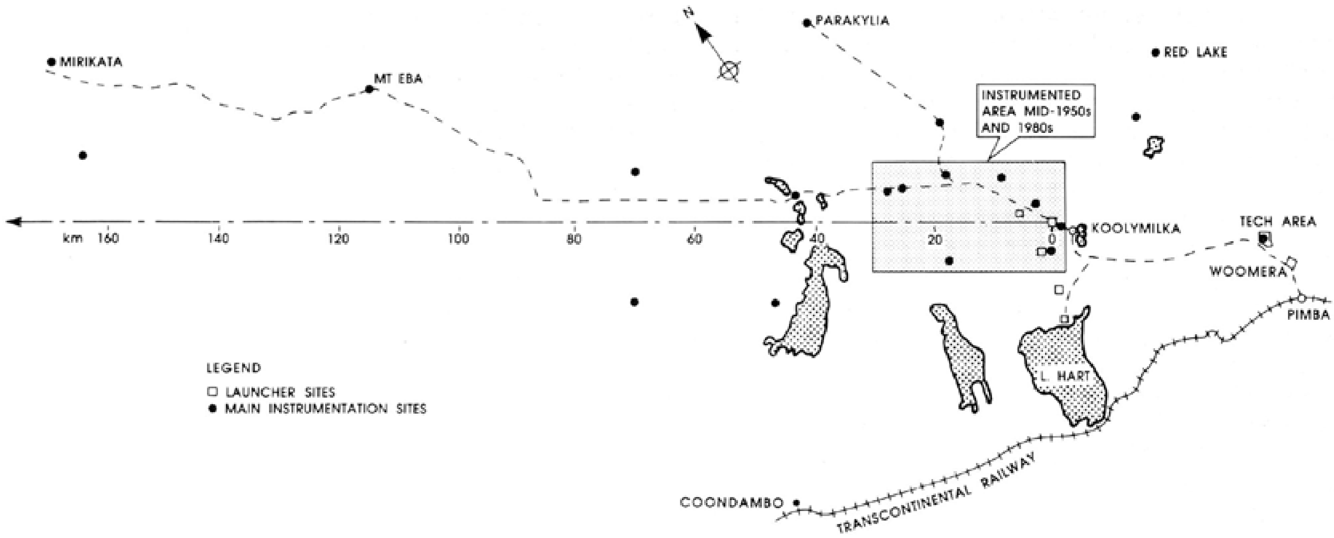
INSTRUMENTING THE RANGES

We recall that the original plan for Woomera's main missile range envisaged a launching and instrumentation complex at the rangehead and a number of observation posts (OPs) equally spaced along the Range centre line and stretching at first for 500 kilometres but capable of extension right across country to the north-west coast. This was to accommodate Menace, the long distance air-breathing missile which was soon abandoned. Early discussions in October 1946 between Butement, Dr Gates of RAE and Lt Col Young of the Radar Research and Development Establishment at Malvern produced agreement that each OP should have a pencil beam radar locking on to a transponder in Menace, so recording its range and angles of azimuth and elevation. After co-ordinate conversion, the data were to be handed to the next OP down-range to enable its radar to acquire the missile in turn, and so on along the whole length. One problem was that putting the OPs on the centre line meant that their radars would have to track up and overhead through the zenith, which no radar of the day could do. One remedy was to design a new radar mount and another was to move the OPs to one side of the flight path. Butement favoured the former.[1]

As things turned out neither solution was called for at once. Woomera developed along quite different lines with no fewer than nine independent and subsidiary ranges



In the early years Woomera had nine independent and subsidiary ranges (Ranges C and D, not shown here, were small dropping areas within Range A). Range E was the only survivor after 1957, and it became the best equipped land range outside the US and USSR.



Range E developed much more slowly than originally planned. By the mid-1950s it was instrumented for only 30 kilometres, and even at its peak the most distant regularly used outpost was at Mirikata 170 kilometres downrange. After 1980 the Range shrank to its mid-1950s size.

being established, of which the main range, Range E, was, it turned out, almost the last to be used![2] They varied in size and importance, and not all were instrumented with any thoroughness. We have already seen in Chapters 10 and 11 that the bomb ballistics range, later known as Range A, was the first to be instrumented (March 1949), followed a few weeks later by the interim missile range (Range F) at the north end of Lake Hart. Range F gave place within a year to the short missile range, Range G, not far from the Technical Area. For the next three years trials activity centred on these two ranges. Range G was 23 kilometres long and was used for trials of ground-to-air missiles, particularly the RTV1 test vehicle. Missile trajectory was obtained from the records of Askania kinetheodolites, an AA No. 3 Mk 7 radar and a three station reflection doppler system. The Askanias were placed near the rangehead and along the northern flank of the range, the radar just behind the launcher, and the three reflection doppler stations were in a triangle, one behind the launcher and the other two on either flank.

Meanwhile Range E was being established with all the facilities—roads, test shops, power, communications and the like—needed for it to become the main missile range. It had an early baptism in 1951 when the Fairey VTO trials were conducted there, but otherwise it was not used until 1953 when RTV1 trials were transferred there from Range G. At that time it was no trans-Australian range and was not to become one for almost a decade. The long range Menace and even the medium range guided missiles had fallen away, leaving only a number of anti-aircraft weapons in the offing. Thus Range E was instrumented for only a short distance down-range, with a rather motley collection of five Askania kinetheodolites, a reflection doppler system with six stations, a few Vinten cameras and a No. 3 Mk 7 radar. But much more was quickly added and by 1957 all the smaller ranges had closed. There were advantages in concentrating all the resources and facilities on one range, given good organisation to prevent interference between the different trials activities. From now on Range E was *the* Woomera Range, and soon was the best equipped land range outside the territory of the superpowers.

DEVELOPING THE INSTRUMENTATION

This process began by studying what was needed and then finding out if any of the equipment was available commercially. If so, submissions and specifications had to be prepared. If not, then the part beloved of the experts began: design work on electronic circuits or lens systems or fine mechanisms, laboratory experiments with experimental lash-ups, and then preparation of the manufacturing drawings. There was more to come: the finished equipment, whether made commercially or in-house, had to be tested, debugged, modified as necessary, and operating and maintenance instructions prepared for it.

In the first year or two of the project little instrumentation was developed in Australia; most of it was imported from Britain and, apart from the Askanias, most of it was made there too. Various MoS establishments built the ground speed cameras for Range A and the telemetry and other systems for Range E. More equipment came from private firms, like the Vinten cameras, or from the services, such as the Army's No. 3 Mk 7 radar.

This procedure was realistic enough at the beginning as the requisite skills were simply not to be found in Australia; but it was not the case for long. In April 1948 Boswell arrived at Salisbury as Principal Officer Electronics to lead the development of electronic instrumentation for the missile ranges. Then the trainees, as they returned from their postings, helped to install at Woomera the British equipment with which they had become familiar; sometimes under the guidance of a visiting expert sent out for the purpose, sometimes unaided. They became the local specialists in their system, and from this it was a short step to developing it further, which meant anything from slight modification to radical redesign and replacement.

Why was this further development necessary? One reason was that much of the early equipment was neither reliable nor particularly easy to operate. Trainees wasted a lot of time at Woomera trying to cure its obscure faults, or teaching operators how to get the best out of it, and so it was in their interests to make it more reliable and operable. But a much stronger stimulus came in the mid-1950s, as a series of new demands for instrumentation at Range E unfolded.

Up to 1953 the trials program had been dominated by the short range RTV1 at Range G and bomb ballistics at Range A. But in that year the preliminary trials of the first guided weapons started, and would later move into the phase of interception trials when missiles like Red Shoes and Blue Sky were to be fired at Jindivik and Meteor target aircraft. This would need simultaneous tracking of both missile and target, and special instrumentation to measure vector miss distance. By 1955 planning had started for upper atmosphere experiments at Woomera using the very high altitude Skylark sounding rocket. But all of these were soon to be overshadowed by the large deterrent weapon Blue Streak and its attendant re-entry research vehicle Black Knight. Between them, these two big rockets would need great effort and expenditure on setting up new down-range instrumentation sites at Mirikata and elsewhere and in developing elaborate safety tracking equipment and an extensive ballistic camera system.

Thus it was that in the mid-1950s many new instruments came to Woomera. Britain supplied some of them as before, but now most were bought or developed by Australia, which now could tackle the requisite engineering. In fact Australia became the senior partner in the joint project as far as instrumentation development was concerned—as it also was in data reduction but never in the guided weapons themselves.

This high pace continued until the mid-1960s. The Blue Streak cancellation in 1960 was a temporary setback, although Black Knight continued and expanded into the Dazzle program which called for special optical instrumentation. But the greatest impetus in this period arose from trials of the ELDO satellite launcher, Europa I, and of the second generation guided weapons such as Bloodhound Mk 2 and VR725 (Thunderbird Mk 2) which had to be instrumented to twice the distance of the earlier first generation Mk 1 versions.

All of this work, which was at times frenzied, transformed Range E into a general purpose range. It had not become so from a desire to cater for all possible future needs. Rather it was a secondary result of the sheer variety of trials projects to be instrumented, with test objects ranging from small bombs to large multi-stage satellite launching rockets, distances from short to trans-continental and heights from ground hugging to well above the atmosphere. Range E could have been started up as a general purpose facility, but this would have wasted funds and effort on instrumentation if it was never used, or if it proved unsuitable or obsolete by the time it was required.

Most of the ex-trainees and others who chose instrumentation regard the decade from the early 1950s to the early 1960s as the golden years, when morale was high, the stimulus strong and the restrictions few. It was the period dominated by Boswell, who had been recruited as an expert in this field and who retained his close interest in it as his responsibilities increased. Although he kept clear of details he encouraged innovation. His approach was to pick out the brightest people for his purpose; often he applied a personal test and if they gave the right answers his confidence in them would be established from that moment. And there is no doubt that those he chose for instrumentation—men like Grahame Lister and M. S. (Kirk) Kirkpatrick—were among the brightest of the trainees. Those who were not quite in the front rank in his eyes were not discarded. Boswell knew how to make the best of his resources. All were integrated into effective working teams where the real innovators were supported by other engineers, scientists and a growing band of technicians.

By about 1965 it was becoming obvious that the great days of instrumentation development were gone for good. In 1968, as a consequence of the Stonehouse agreement, there was a drastic reduction in the human effort devoted to it. A few specialists were retained, but most turned entirely away from the joint project towards all-Australian defence research. Until the mid-1970s the instrumentation actually installed at the Range was in a static phase where it was living on its capital, with little new being added and most of the effort directed to maintaining what was there. Then the final phase started of dismantling what had been built up over the years, the end result being only a small remnant no bigger than its predecessor of the mid-50s, which sufficed to handle the modest post-project trials program. There was a parallel run-down of the remaining experts: many were redeployed elsewhere and the rest, including a few grizzled veterans of the 1950s, remained until they retired.

ORGANISING THE INSTRUMENTATION STAFF

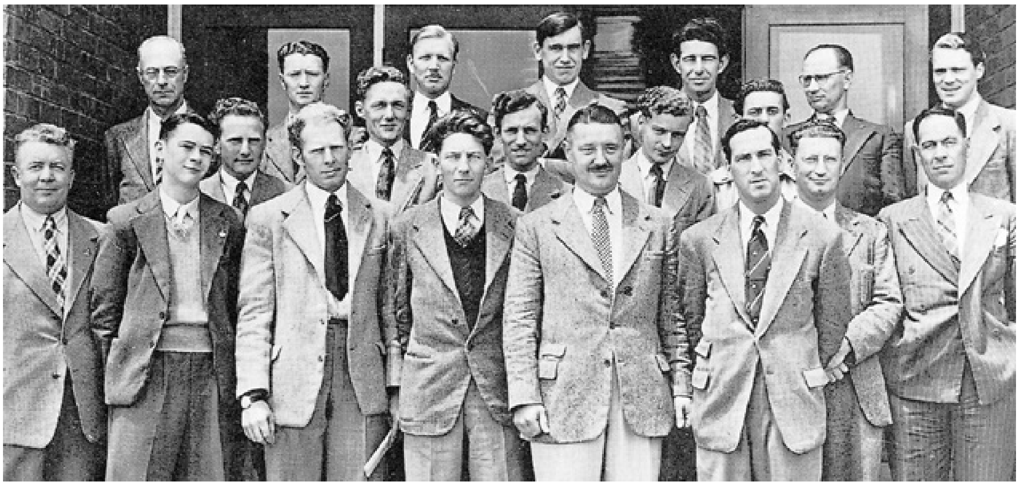
A good proportion, at least a third, of all the employees of the joint project worked on instrumentation in its various aspects: some developed it, others planned how it was to be used for each trial, others set it up and operated it and maintained it in between, others worked on ways of improving its performance, and still others processed the records produced by it. Each task needed special skills and each was the province of a particular group of people.

For economy's sake most of these staff worked at Salisbury, but a resident Woomera staff numbering several hundred in the 1960s were still required, simply because all the installed equipment was there and trials continued week after week without a break except for the month-long Christmas stand-down. Even so, the Woomera staff had to be augmented by extra people from Salisbury for the occasional major trials such as the Europa launches.

In the early years the instrumentation at each of the separate small ranges was operated and maintained by a mix of uniformed residents and civilian visitors from Salisbury. The servicemen were part of an integrated Australian inter-services organisation with small contingents from the Army, Navy and Air Force, under the Range Superintendent, Brigadier Neylan. By about 1953 the servicemen had been replaced by civilians, but in many cases they were the same faces—men who had chosen to be demobilised and were now returning as Supply employees. For example, H. D. (Sid) May first arrived at Woomera in 1950 as a nuggety young Navy petty officer, to operate the central timing equipment at Range G. After two years away he returned in 1960 as a civilian technician on the Range E telemetry, and he was a Senior Technical Officer still on telemetry work when the project ended; by then he had spent twenty-seven years at Woomera.

In 1955 the instrumentation staff at Woomera were transferred to a new Ranges Group which lasted unaltered for over twenty years. Most of this group were technical or photographic grades, supervised usually by Experimental Officers—professional engineers and scientists. The professionals and technical grades were generally recruited from the instrumentation groups at Salisbury, and were expected to serve three or four years at Woomera before returning there—at least until the mid-1960s when getting back became more difficult. The photographic staff, most of whom operated optical instruments such as kinetheodolites and tracking cameras, were usually recruited from outside WRE. However, the junior grades did not qualify for housing at Woomera, and so these places were filled by village residents: typically the wives and daughters of the male staff. These women needed no formal qualifications, but most were young and keen sighted, and after training on the job made excellent kinetheodolite operators. They saved the Range from being entirely a male preserve, as very few other females worked there. One of them was Laurine Hall, a strapping young woman who rode a motorcycle with her long blonde hair streaming and decorated her Askania post K2 with chintz curtains. She was a familiar identity in the late 1950s and is described with fascinated admiration in Ivan Southall's *Woomera*.[3]

Back at Salisbury developing the instruments was a task assigned to specialist Groups. The first such were Boswell's Electronics Group and Bonnell's Optical Group[4], both set up to provide the instrumentation for the missile ranges: Range A instrumentation was supplied by a section of Bomb Ballistics Group. In 1953 the latter became Air Instrumentation (AI) Group, while parts of Optical and Electronics Group were reformed



Optical Group in 1959

into Missile Instrumentation (MI) Group. The 'air' and 'missile' sides were merged in the 1955 reorganisation, but the functional split between electronic and optical-mechanical returned and, after another interchange of staff, AI and MI Groups reappeared as Optical and Mechanical Instrumentation (OMI) and Electronic Instrumentation (El). There was also a new Techniques Division, set up to provide technical support by investigating such matters as improved lens design for OMI and aerial systems for El. In practice the distinction between instrumentation and techniques was sometimes rather arbitrary. In 1962 El Group was split in two, forming Electronic Tracking Systems (ETS) and Telemetry Systems (TMS), but this last fission marked the limit to expansion. A few years later in 1968 all the instrumentation development and support work contracted into a single group, Instrumentation Systems (INS). INS survived the end of the project though with steadily falling numbers, absorbing on the way what remained of the disbanded Ranges Group.

The instrumentation groups were normally organised around particular systems: thus El Group had a doppler section, a radar section and so on. This was preferred to a division based on the disciplines of optics, fine mechanics and electronics because few systems fell exclusively into a single category even though they were normally classified as one or the other for convenience. For example, the Contraves kinetheodolite was a precision mechanical instrument with complex optics and elaborate electronics driving the mount and synchronising the camera. Accordingly the Contraves sections in Optical Group and in Ranges Group contained electronics, mechanical and optical experts. Within the Groups certain people came to be recognised as the most knowledgeable about particular systems: men such as Paul Gillard on telemetry, John Rodger on acquisition and real-time displays, David Miller on the Contraves. In 1961 this was formalised when twelve of these experts were nominated as Systems Authorities and given defined responsibility for monitoring the performance of their equipment.

Working closely with the instrumentation groups were several sections of what became the Engineering Wing of WRE (and much later the Advanced Engineering Laboratory). The experimental versions of many instruments were made in small workshops attached to most of the instrumentation groups, and then constructed in the well-equipped mechanical and electronic workshops of Engineering Wing, or by outside contractors. Engineering Wing had experts at design and planning who transformed rough experimental layouts into reliable and properly documented equipment. One group within the Wing, Engineering Development and its successors, tackled the mechanical engineering design of optical instrumentation and provided the drafting services. The other was Electronics and Communications Division (E&CD). This Division and its predecessors installed most of the electronic instrumentation at the Range, such as the timing and communications centre in the Instrumentation Building with its rows of equipment and multitudes of neatly stacked overhead cable connections to the distribution frames. Many of its staff had come from the Postmaster-General's Department (the part later absorbed by Telecom) and E&CD was also the main link between WRE and the PMG when the latter was installing the vast and expensive web of underground and overhead land-lines to all the dispersed posts throughout the Range. Engineering Wing's close support of the joint project lasted until the reorganisation of 1968, after which it turned to all-Australian work.

No less important than the staff who built, installed, operated and maintained the instruments were the ones who worked out how they were going to be used in a particular trial. After the integration of air and missile trials in 1955, all planning was in the hands of Missile Projects (MP) Group. MP Group's Trial Instruction specified what instrumentation was to be used and how it was to be deployed. The sponsor of the trial, the Range user, had to describe to MP Group and others exactly what measurements were needed for the trial, with what sampling rate, for how long, and so on. For example, the Range user might ask for a missile position to be fixed to an accuracy of two metres from launch to interception, at 20 points per second. The Trials Instruction would then specify that certain Contraves should track the missile throughout, with their cameras running at 20 frames per second.

There was a parallel activity—project planning. This was done at a much earlier stage, well before the first trial, and usually involved a visit by a mission from Britain or elsewhere. At this stage the Range user would probably have carried out preliminary trials already and so would have some notion of what he expected to get from his trials at Woomera. The mission meetings, often lengthy affairs, would be attended by all the instrumentation people likely to be involved, plus the data reduction people. Range user missions familiar with WRE's approach found the going smooth enough, but with others difficulties often arose. A typical argument might run something like this:

> WRE: Now, what information do you want from this phase of your trials?
> Range user: Oh, we would ask for Contraves backed up by your Adour radars, plus the usual Vinten cameras. We'll let you know which instruments when we plan the particular trial.
> WRE: No, that won't do. Please tell us now what information you want: accuracies, maximum values, sampling rates and so on. It's our job to work out what instrumentation we'll use, not yours!
> RU: But we know what instrumentation you have. There's no point in asking for something you can't provide.
> WRE: Again, that's our problem. If you really need information we can't now give you, we'll have to consider extending the instrumentation.
> RU: In that case we'll have to study our data requirements more closely. Can we postpone this discussion until tomorrow?

This rigorous approach, pioneered by Boswell and vigorously maintained by Lawrence and his successors, probably irritated the members of some missions, but WRE was not apologetic about it. It forced the missions to define what they really needed, and it pinpointed any deficiencies in instrumentation cover while there was still time to do something about it.

Once the Range user had confirmed what he needed and WRE had agreed to provide it, everything was recorded in an instrumentation proposal which formed part of a project planning specification. Funds for any new instruments were then sought. Of the many millions of pounds spent on the greatly expanded instrumentation network of the Range during the late 1950s and early 1960s, nearly all was approved because of the big new projects of the day: Blue Streak, Black Knight, Blue Steel, Europa, Bloodhound Mk 2 and so on.

Project planning was at first co-ordinated by MP Group, but in 1959 a separate Projects Assessment (PA) Group was set up under E. C. (Monty) Montgomery to do it. For a while there was a third group as well called Instrumentation Programming and Progressing (IPP), but this marked the limit to expansion. It turned into contraction in 1968 when a new Planning and Data Analysis (PDA) Group took over both project and trial planning and the trials data reduction and analysis work as well.

To complete the picture of how matters were organised, it should be said that all the films from the instruments (kinetheodolites, cameras and telemetry) were at first processed by Optical Group and later by OMI Group after new continuous processing machines were set up in the Laboratories Area in 1954. Later the work was handled by a new Range Support (RS) Group, headed first by Phil Norman and then by Jim Frost. As its title suggests, RS Group was established to assist in Range operations, and particularly it was supposed to man the remote instrumentation sites planned for Blue Streak, including those over on the other side of the continent at Talgarno. It survived the cancellation of Blue Streak in 1960 because it had been given plenty of other work: not only film processing but operating a new Salisbury telemetry replay station, writing instruction manuals and support work on Vintens and other cameras. INS Group absorbed RS Group in 1968 and took over its work, but most of it disappeared in the final run-down of the late 1970s.

OPTICAL INSTRUMENTATION

Those Range instruments that used visible light to detect objects during trials were known collectively as optical instrumentation. Occasionally the system was called photographic instrumentation instead, but, as some devices like the photo-electric flash detectors, optical trackers, skyscreens and TV cameras did not use film, this was not strictly correct.

Optical methods were exploited at Woomera from the beginning. The reason is not far to seek on a semi-desert Range where the sky was so often a dome of flawless blue. In most years the sun shone for more than 3300 hours, and on average the sky was completely overcast for only two or three days a month in summer and five or six in winter.[5] The transparent air and fierce light together gave superb visibility, except during the brief spells of rain and the occasional dust storm. The only serious problem was the thermal currents common to all hot arid parts of the world, which caused atmospheric shimmer or 'boil' during the summer months. Most affected were the longer focal length cameras and kinetheodolites at low elevations whose lines of sight ran close to the ground. Under such conditions distant objects would be blurred and appear to dance sinuously. Optical Group investigated this problem closely, taking measurements of 'seeing' conditions throughout each day for a whole year. Eventually they were able to predict the conditions to some degree and could advise when crucial trials might best be held. Two general solutions were to work early in the morning before the thermal currents developed, or to place the instruments on towers well above the ground, as was eventually done with the Contraves.

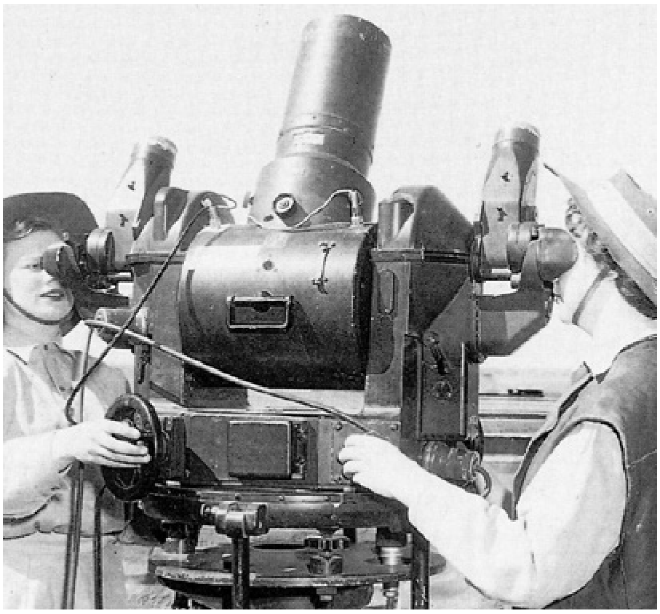
Optical instruments came into their own at Woomera for making permanent photographic records, from which most of the precise measurements of trajectory and attitude were derived. Optics were not so useful for obtaining information in real time, although in the earliest stages of a flight the rising missile was tracked optically and skyscreens were used for safety surveillance. For the purposes of navigation and safety tracking radio systems such as MTS and the later radars were supreme because of their longer range and their ability to penetrate clouds and fix a position instantaneously.

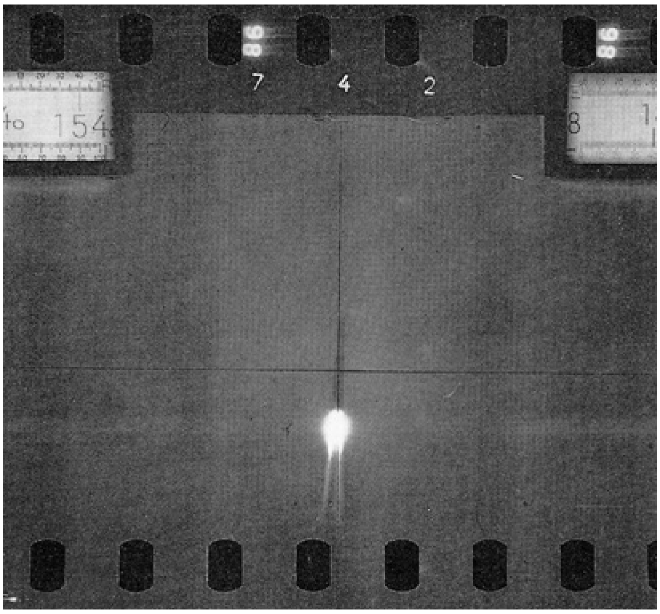
ASKANIA KINETHEODOLITES

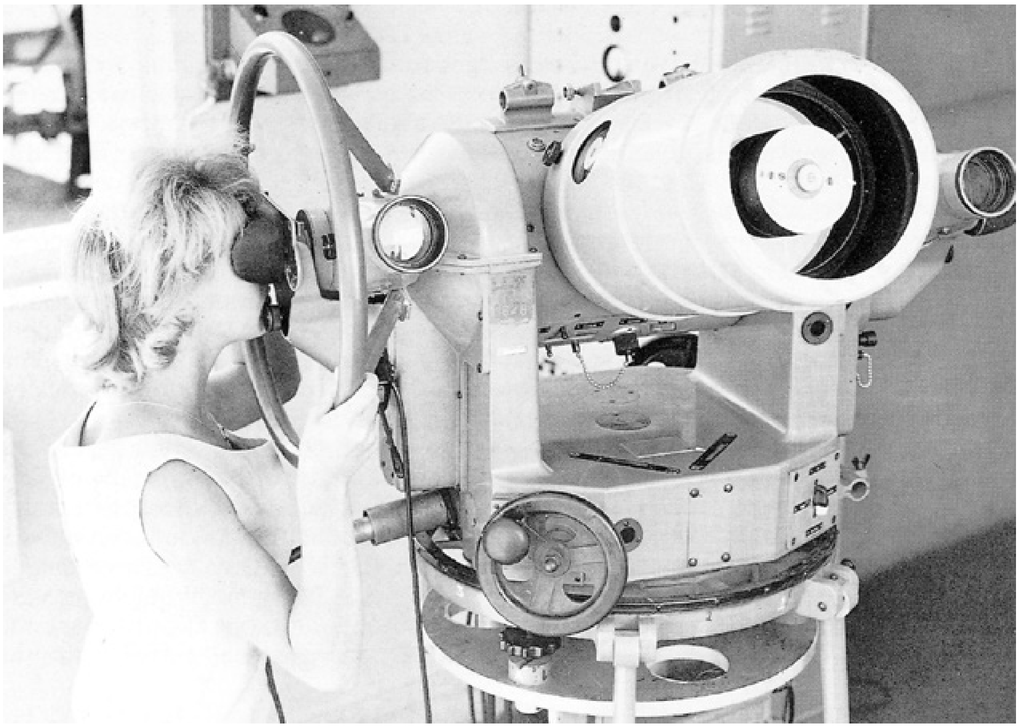
A kinetheodolite is an optical tracking instrument that is both a theodolite and recording cine camera. From its azimuth and elevation scales can be read the horizontal and vertical angles of the optical axis of the main telescope. But these scales are not read by eye as with a surveyor's theodolite; rather they are photographed at regular intervals by a cine camera, along with pictures of where the object is at that instant relative to the optical axis. The number of each frame is also recorded and from this each exposure can be timed, as the

Below left: An early KTh41 at Range A being operated by turning geared handwheels.

Below: A single frame of an Askania kinetheodolite showing the azimuth (A) and elevation (E) scales and also the frame number (742). The scale readings are corrected by measuring any error in tracking the object—here the satellite launching rocket Europa.







A KTh52 Askania fitted with direct acting handwheel and 1000 millimetre mirror lens.

cameras of all kinetheodolites in use are synchronised. The position of the object at each exposure can be calculated from the records of at least two kinetheodolites simultaneously tracking it. The result depends of course on how accurately the two instruments have been levelled, oriented and their positions surveyed.

The first kinetheodolites at Woomera were manufactured by the German firm Askania-Werke AG and were booty taken by the British near the end of the war in Europe. They came to Australia in 1948 and were the KTh 41 model, the digits signifying the year of manufacture. Thus they were already seven years old on arrival and had to be fully overhauled and refurbished at Salisbury, a job entrusted to Ron Nicholson, a newly recruited instrument technician in Optical Group. First he had to strip them to find out how they worked, as they came without manuals.

The Askanias were taken up to Woomera in 1949 and two of them installed on the new bomb ballistics range (Range A) in an attempt, not often successful, to track bombs from release to impact and thus measure their trajectory. At about the same time three Askanias were used at the interim missile range (Range F), where at first they were simply removed from their boxes and stood on bare earth. Later they were housed in vans and when Range G was set up early in 1950 as a replacement for Range F the three vans were moved there. Another five Askanias were put on Range E, initially in late 1950 for the Fairey VTO models, and five more on Range A1 in 1953 for the Blue Boar gliding bomb. Those on Ranges A, A1 and E were supposed to be permanent and were installed in brick huts with sliding roofs, but only the Range E posts survived the closure of all the smaller ranges in the mid- 1950s.

The Askania had been designed to track at relatively slow rates, as it was used for bomb ballistics work and aircraft trials at various German ranges and for V2 trials at Peenemünde. It needed two operators: one to track in azimuth and the other in elevation, each one sighting through an elbow telescope and turning geared mechanical handwheels to keep the object in view. This worked quite well with the slow tracking rates usual in bomb ballistics trials (provided the bomb was big enough to be seen) but the handwheels simply could not be turned quickly enough to keep up with fast missiles at close range.[6] There was another problem: capping shutters opened momentarily at each exposure to photograph the azimuth and elevation scales by the light of tungsten lamps. At high tracking rates the exposure time was too long, making the scale images too blurred to be read accurately. Also each kinetheodolite worked to its own time, with neither the scale exposures nor the main shutters synchronised to those of the other Askanias being used.

In the early 1950s the optical technicians found remedies for these problems. They turned the Askania into a one-man instrument simply by disconnecting the handwheels and fitting handlebars and a pair of 45 degrees angled sighting binoculars over the main lens. Later the handlebars were swapped for a large elevation hand-wheel on the side and one of the original side tracking telescopes. This made it much easier to use as the operator no longer had to stoop to track in elevation. Laurine Hall, who operated the Askania K2 post around 1960, once graphically described the tracking problems of the old handlebar instrument:

> And then with Black Knight, following it up and up, so straight up that it forces you down to the floor on your ankles, and your legs are straining and trembling and your back nearly breaks. At flame-out I collapse in a heap on the floor.[7]

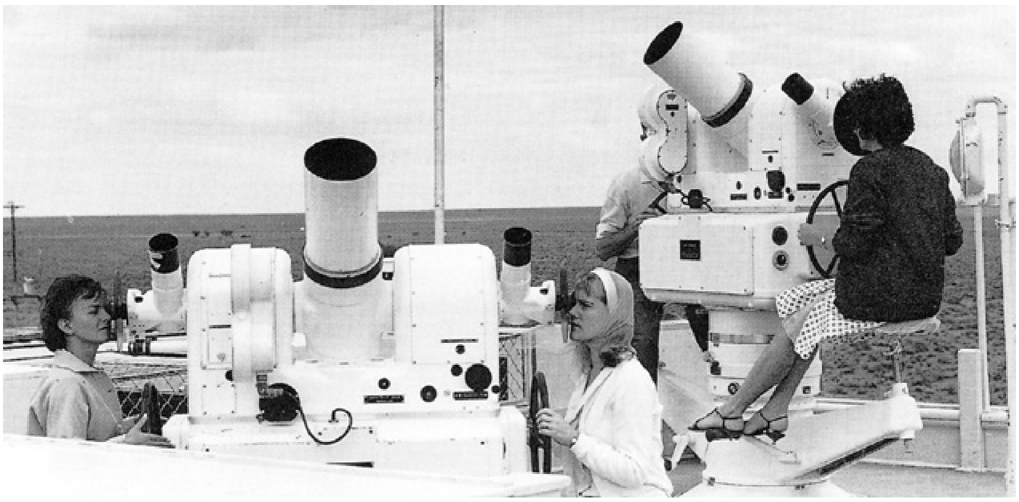
The other problem of the blurred scales was solved by replacing the tungsten lamps with two small U-shaped mercury flash lamps, specially made by GEC in Britain. These were triggered electronically from a common time signal of 4 pulses per second, so that the very short scale exposures, as well as the main shutters, were synchronised in all the Askanias in use. This froze the scale exposures and made the timing much more accurate. But the biggest drawback of the Askanias was never solved. Its camera was not really a cine camera, but exposed successive frames by electrical pulses at a maximum rate of 4 per second. Between each pulse was a pause while the film wound on: it lasted about a quarter of a second. In that time a fast missile might have covered 150 metres, so the sampling rate was quite inadequate.

Despite their slowness the Askanias served Woomera well in the early years and, although they were out-performed by the Contraves instruments which began to come into use late in 1955, they lasted for a long time. The five at Range E were replaced by more modern KTh 52 models in 1955, and later were given larger lenses with better resolution. All the Askania sites were quite close to the rangehead, stretching in an arc from K2 behind the launcher to K6 on the right flank 4.5 kilometres away; and with their comparatively wide field of view they were usually able to track missiles in the early stages of flight. At times the few trajectory data points they produced could be invaluable if the Contraves happened to be late in acquiring. Then again, the Askanias could be adapted for special jobs. In the late 1950s one was installed at each of three ballistic camera sites in a fruitless attempt to photograph the elusive re-entry of Black Knight, and in 1964 three were set up near Launcher 6 to record the early stages of the flight of the satellite launcher Europa.

Eventually, with the run-down, nearly all the Askanias went at disposal sales for a few dollars apiece. But because they are quite transportable a few even survived the end of the project and continued to be used on various forces exercises and trials, though not at Woomera.

CONTRAVES KINETHEODOLITES

The Contraves kinetheodolite was an instrument much superior to the Askania, for it had been designed some ten years later. The makers guaranteed its accuracy within 20 seconds of arc, even when tracking a moving object, and after readjustments by Optical Group the ones at Woomera did even better than that: the network on the main range was generally reckoned to be capable of locating any object in observational range to within a maximum of 3 metres.



Contraves kinetheodolites K11 and K12 being operated.

The Contraves was much easier to track with than the Askania. It had a power driven mount which was servo controlled by two sensitive handwheels, each wheel being manipulated by one of the two operators who set the rate of tracking in azimuth and elevation. Turn say the azimuth handwheel a little and the mount rotated at a constant rate; turn it a little more and it rotated faster—right around in 6 seconds. Quite a lot of operators were needed to man the dozen or more Contraves called up for a complex trial, but the training was simple enough. All the operators had to do was look through an elbow telescope and adjust the handwheel so as to keep the object being tracked level with a central line in the eye-piece. They sat on saddle seats which were carried around the mount but were physically separate from it to eliminate vibration.

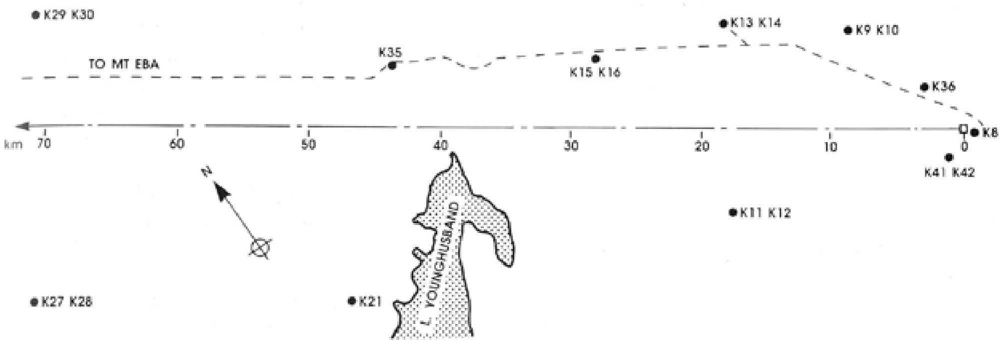
Apart from its tracking accuracy, the Contraves' great advantage was that it could expose its film at either 10 or 20 frames per second.[8] The higher rate, five times that of the Askania, multiplied the number of position data points that could be read, allowing velocity and even acceleration to be derived by successive differentiation. Furthermore, the Contraves used 35 millimetre film which fitted an ordinary cine projector and so could be shown on a large screen afterwards as a behaviour record.

It was better than the Askania in other ways too. With its servo system it could be put under the direct control of a distant radar which pointed it in the right direction until the operators spotted the object and took over manually; a very useful feature for posts too far away to acquire the missile immediately it left the launcher. Those much closer often lost track of the missile during its initial fierce acceleration. To help them, Contraves supplied WRE with Predetermined Function Generators (PFGs) in 1967 for the forthcoming Rapier trials. Their purpose was to feed precalculated azimuth and elevation rates into the instruments for the first few seconds, before the operators took control. Unlike the elegant kinetheodolite itself the PFGs were rather crude devices relying on two motor-driven cams, each specially cut to suit the predicted rates for that missile. In fact they were virtually unused in the early Rapier trials. It was not until the early 1970s, when the Contraves were asked to track missiles with particularly high accelerations off the launcher, that PFGs came into their own.

LRWE first became seriously interested in the Contraves in 1953. At the beginning of the 1950s the crucial instrumentation problem faced by LRWE was how to measure trajectory, vector miss distance and missile attitude during forthcoming interception trials of the first generation guided weapons. The Establishment tried several approaches, all of them were abandoned for one reason or another. Optical Group spent time designing its own kinetheodolite of very advanced design, and then effort was diverted to a variant known as the Optical Target Engagement Recorder (OTER) which was not a kinetheodolite but a long range tracking camera using 70 millimetre film, intended to record miss distance and missile altitude only. Lacking scales, it could not be used for trajectory which would have had to come from the Askanias and doppler.

By 1952 matters were urgent because of the forthcoming Red Shoes and Seaslug trials. Fortunately Bonnell had already heard of a superior kinetheodolite being developed in Switzerland. The Zurich weapons firm of Contraves AG (from the Latin *contra aves*: literally 'against birds'), a subsidiary of the Oerlikon Tool and Gauge Company, had earlier faced problems similar to LRWE's in instrumenting trials of one of its anti-aircraft guided missiles. Having found nothing suitable on the market Contraves developed its own kinetheodolite, with considerable help from Swiss instrument makers such as Kern, the manufacturer of surveyors' theodolites. The result was so successful that Contraves put their Electronic Optical Tracking System (EOTS) on the market, selling twenty-five of the first version to the American White Sands Range.

Having read everything he could find about the Contraves Bonnell decided that with some modifications it would probably serve LRWE's purpose. He went to Switzerland where he found Contraves had set up one of their first instruments on a hilltop above a base of the Swiss Air Force, whose aircraft were used in tracking exercises. Bonnell took part in these and satisfied himself that the kinetheodolite was superior to any other instrument available and that it could be modified in time to suit the Range requirements. The Contraves could not be depended upon to record both target and missile on the same frame, so enough instruments would have to be set up on Range E to measure the trajectories of both missile and target, from which miss distance could be deduced. The Askanias were far too slow and inaccurate to do this. Further, the Contraves' 1500 millimetre lenses could give images large



Disposition of the Contraves kinetheodolites on Range E. They were favoured for measuring trajectory.

enough to measure missile attitudes, providing the missile was not too small or distant. Bonnell therefore recommended that eleven of the new kinetheodolites be ordered: seven for Range E, one spare and three for Range A to record bomb trajectories. After the Board of Administration had approved, an order worth £262 000 was placed on Contraves AG in mid-1954.[9]

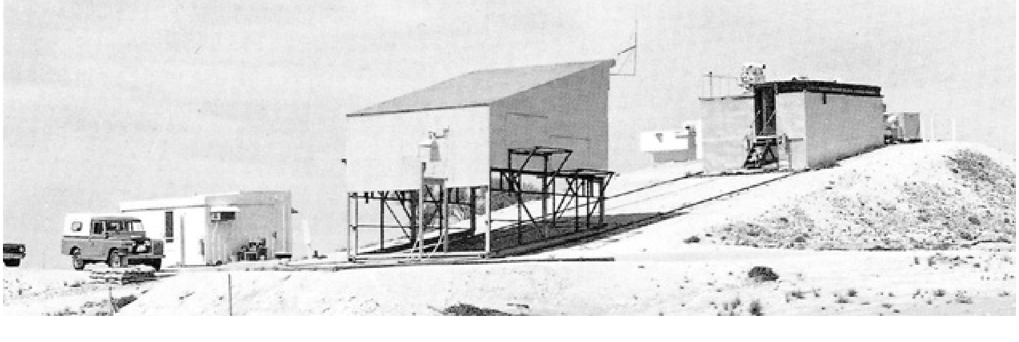
In October 1954 David Miller of Optical Group went to Zurich for six months to learn all about the equipment and to act as technical liaison officer. Miller, who had a passion for fine mechanisms, found the legendary Swiss genius for precision engineering very congenial. On his return he became the acknowledged expert on the Contraves, which remained his chief interest until he retired in 1979.

The first six Contraves were delivered late in 1955 and by the end of the year three had been installed on Range E: one (K8) on the roof of the Instrumentation Building and two more (K9-K10) at a twin site 9 kilometres down the right flank of the Range. (At the twin sites one instrument tracked the missile and the other the target.) With the arrival of three more in the following year two additional twin sites were added: K11-K12 17.5 kilometres down the left flank, and K13-K14, 18.5 kilometres down the right. Range E now had sufficient instrumentation for the first short range interception trials. The two remaining Contraves of the nine delivered so far were used as spares and for testing and development work at Salisbury.

The twin sites were housed high above the plain in what looked like a large skillion roofed shed on top of an artificial mound and ramp. At the press of a button the front of the shed rolled up and then the roof and sides slowly slid down the ramp on rails, exposing the two instruments. Both had an unimpeded view: the rear one was higher, so that it could see over the other and follow the target aircraft around its whole track.

The last two kinetheodolites of the purchase order were modified in Switzerland so they could form part of the acquisition system at the Range by being put under the control of a distant radar. Miller was there at the time (1955) and he recalls getting the necessary computer to meet its specification cost Contraves a great deal of time and effort; apparently the firm had not realised the dimensions of the task until they started on it, at what proved to be a bargain price for WRE. Still, by 1957 the two remaining instruments and the acquisition computer had been delivered, and so a fourth twin site was instrumented: K15-K16 28 kilometres down the right flank, the remotest site at the time and thus the one most in need of help from the acquisition system.

All this was finished in 1958, by which time long range tracking cameras had also been set up and the target aircraft fitted with cameras mounted in wing pods to record the miss distances at close range. The interception trials of the first generation guided weapons were adequately instrumented at last. But by the following year new demands were looming. The longer range second generation weapons were emerging and one of them at least, Bloodhound Mk 2, would need trials on Range E with interceptions well beyond



A Contraves twin site ready for trials, with its protective shelter rolled down the ramp.

K15-K16. The decision was taken to buy six more Contraves and install four of them at two new twin sites 70 kilometres down- range, one on the left flank (later named K27-K28) and one on the right (K29-K30).

The two other kinetheodolites were to be used as spares in the maintenance program. However, by delivery time one of the spares had been allocated to K21, a new post 45 kilometres down the left flank, established to help fill in the long gap between K15-K16 and the 70 kilometres sites. K21 already had an opposite number on the other flank. In 1959 Ranges Group had placed unofficially a spare instrument at a new site (K22) some 40 kilometres down the right flank, in an attempt to improve coverage of certain longer range Bloodhound Mk 1 trials. K22 was not very successful: it was on a concrete slab on top of a small sandhill, not quite high enough off the ground for good 'seeing'. Communications services were simply tapped off the nearby open wire line to Mt Eba, and the timing was often troubled by interference from pastoralists' telephone conversations. In 1965 the rudimentary K22 was replaced by a new properly installed post K35 on an elevated site with better communications.

Apart from K22, all these down-range sites were built to a new plan. Each kinetheodolite was bolted on top of a monolith several metres tall, made of concrete sewer pipes filled with concrete standing end on end in deep foundations. The monolith was surrounded by a tall hut on separate foundations with an upper floor at the top on which stood the operators and their ancillary equipment with a motor driven hinged roof above them. The kinetheodolite base was level with the floor but separate from it, the intention being to guard it against thermal distortions and vibration.

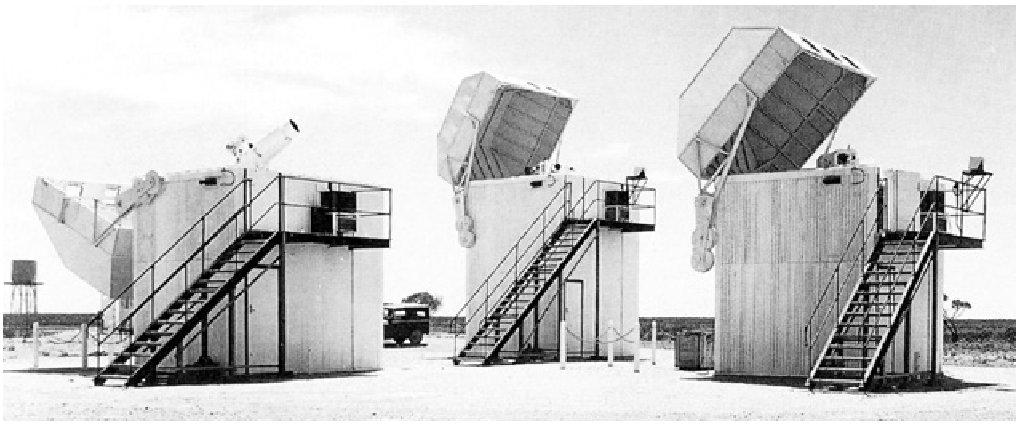
Kinetheodolites were installed at K27-K29 at the end of 1961 and the sites commissioned in April 1962 when acquisition, timing and communications services were connected. The others, K21, K35 and K28-K30, followed in September 1962. Ron Nicholson later recalled the installation of these down-range sites:

Ron Nicholson.

> It was a fair way from the Woomera village and we tended to live down on the sites. We had a multitude of electronic vans for the digital acquisition system and timing and we just got mattresses from Woomera and blankets and took a whole mass of food down there and we slept and cooked our own meals. One man worked for Comms Group and he was an excellent cook—he could make a really nice meal out of tinned camp pie. There were numerous problems of course, especially with the acquisition system . . .[10]

The Contraves system did not develop much further in later years. For the Rapier trials in 1967 an instrument from one of the 70 kilometre sites was transferred to a new post, K36, 3 kilometres down-range on the right flank, filling a gap between K8 and K9-K10. Later two more of the 70 kilometre instruments were withdrawn and installed at a new twin site, K41-K42, about 2 kilometres down-range on the left flank. All these later sites used the same construction as those down-range, except that K36 was mounted on a higher 9 metre tower because it was sited in slightly lower country.

Part of the Contraves system survived the Range run-down. All four 40 kilometre and 70 kilometre sites as well as K8 and the left flank site, K11-K12, were removed, but the others remained to give a system which now looked much as it had been in 1957. But K15-K16 and its two precision instruments were reduced to charred masses of metal and melted glass in a fire of February 1983. Much to Nicholson's chagrin, one of the Contraves had just been painstakingly overhauled.

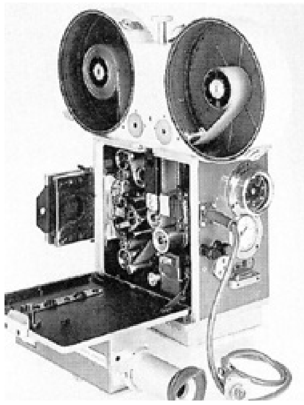


A downrange site, equipped with two kinetheodolites and a Rakimo (*at left*).

BEHAVIOUR CAMERAS

The instruments known as behaviour cameras or sometimes performance cameras did not form a network like the Contraves system, which at its peak consisted of seventeen nearly identical linked instruments. Rather they were a motley collection of different cameras mounted on anything from simple columns to sophisticated servo tracking units and equipped with any kind of lens up to 5000 millimetre focal length Cassegrain telescopes. There were also ancillaries such as motors, gearboxes and electronic drive and timing units.

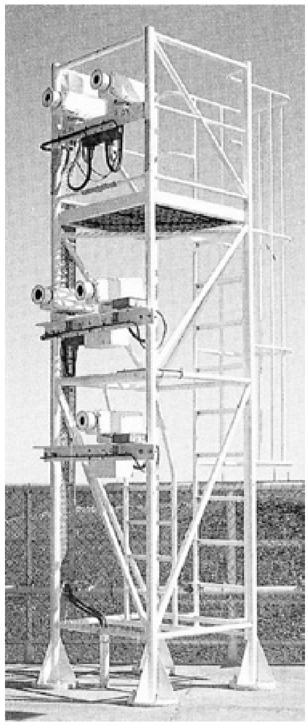
The cameras were all cine or special cameras set up to film the flight of missiles and other test objects during trials. They were precision instruments which all recorded timing pulses on the film, and all could run at speeds many times the standard motion picture rate of 24 frames per second. These features were essential because the films had to make precise measurements of the times when events happened and often to record attitude angles and even position. From beginning to end of the joint project, the most commonly used camera was the British precision, hand-finished Vinten HS300, which could expose up to 250 frames a second. They underwent only one modification. In the original camera timing marks were recorded along one edge of the film by a spark flashing inside a small box with a slit in it. Each camera had its own timing, provided by an electrically maintained tuning fork with contacts at its extremities, which triggered the spark gap through an ignition coil just like a car ignition system. This apparatus was sometimes unreliable and could not be synchronised easily with other instruments timed from a central source. Also the unsuppressed sparks could cause electrical interference. By 1953 LRWE had replaced the spark gaps with tiny mercury vapour flash lamps, and the tuning forks by timing pulses from the Central Timing Units at each range. Thirty-seven Vintens eventually accumulated at Woomera, and many were still being used there years after the project finished. They were so solidly constructed that regular overhauls kept them going indefinitely.



A Vinten HS300 cine camera. They were the normal choice for recording behaviour throughout the joint project, and some are still in use.

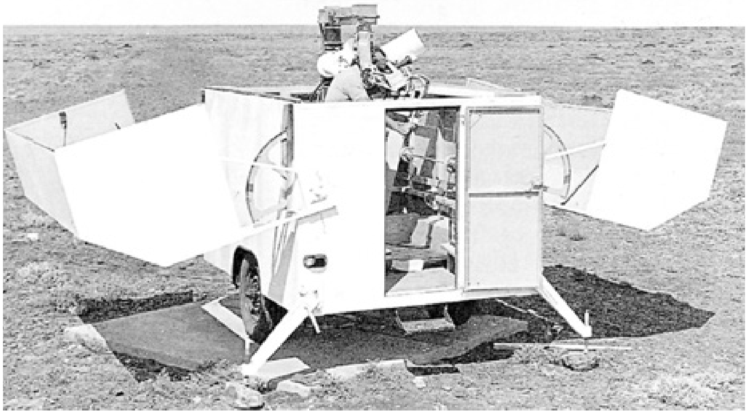
The Vinten was not the only behaviour camera. Even higher speed cameras such as the Fastax and later the Photosonics 4C were needed on occasion, particularly for interception trials with live warheads when the damage to the target had to be photographed at close intervals. Other special cameras were designed to work in hostile environments, such as the 16 millimetre camera which recorded the dramatic light-up of the Blue Streak rocket nozzles in the early Europa trials from only a few metres away. Some of these special cameras were not bought but developed at Salisbury. The earliest example was the acceleration or ribbon frame camera, whose development started in 1949. Its purpose was to record the acceleration, attitude and behaviour of guided missiles as they sped from the launcher. Its 140 millimetre wide film moved continuously over a drum and was exposed for very brief instants lasting 100 microseconds by a horizontal slit in a whirling cylinder which surrounded the drum.

The launcher cameras were usually on simple fixed mounts oriented to cover the expected zone of interest and, being too close to the launcher to be manned during trials, were operated remotely and automatically. They were not installed permanently but could be taken to any of several hundred prepared positions, each being little more than a patch of concrete with a surveyed mark in the middle, an outlet for communications and timing, and sometimes a power supply.



A battery of 16mm remotely operated launcher cameras set up for a Europa trial.

From a safer distance manned Vintens on tracking mounts were used to follow and record the flight of the missile. Most of these tracking mounts were developed at Salisbury, some of them by freely adapting existing mechanisms manufactured for other purposes, particularly the ubiquitous mount for the No. 3 Mk 7 aerial dish. The first tracking mounts were of the trunnion type, operated manually. Behind the camera stood one man (it was usually judged too heavy for women) using handlebars to move the ponderous Vinten with its motor and big 900 millimetre refractor lens in both elevation and azimuth as he sighted through tracking binoculars. As with the similar system on the early Askanias he had to walk around the mount and stoop as he tracked across and up. Such trunnion mounts were first used in 1949 on Range F and then Range G, and were fitted in trailer vans like most of the instrumentation at these ranges. When Range E opened more trunnion mounts were fixed on the Instrumentation Building roof, on towers and on top of some of the few natural mounds in the flat landscape. Some of the Range G trailer vans were transferred to Range E, but being difficult to shift they tended to stay put. Eventually they deteriorated and were withdrawn. By 1954 a more mobile camera had been developed: a trunnion mount was installed on the back of a white International panel van. The rear half opened up to give the



An 'EMU' mobile camera van (*above right*), and the trailer that replaced it (above).

The overhung mount developed by Herbst, with Zeiss 1000 millimetre reflector lens.

camera on its cut down trunnion mount a clear view over half the horizon and up to zenith. Camera technician Ron Edmondson dubbed it EMU (for Easily Movable Unit, although the acronym came first), with a Disney-style motif of a running emu on the side. By 1957 there were three EMUs on Range E and very useful they proved in coping with the heavy trials program in the late 1950s and early 1960s. An EMU could be shifted to another site and be operating again in half an hour, and they could be used at any prepared site including the VL launcher camera posts.

For more than a decade every tracking Vinten site within about 10 kilometres of the rangehead had simple trunnion mounts, but their performance was patchy. Some operators liked them but others found them awkward. Witold Herbst of Optical Group was asked to design a better mount in the early 1960s, and he came up with an ergonomic design which allowed the operator to keep his feet still while moving the camera with handlebars through its full traverse, simply by turning his hips and raising or lowering his head. The Herbst mount had an overhead vertical axis supporting a yoke and a horizontal axis just behind the operator's ears. The prototype was tested in about 1967 and soon demonstrated its tracking superiority, although it did not replace the trunnions entirely for some years. It was expensive to build, and eventually was redesigned to use commercial hydraulic jacks in the main column to adjust the height, thus saving several costly precision machining operations.

To go with the new overhung mount a better lens was needed to replace the heavy poor quality 900 millimetre refractor lens. After many inquiries David Miller found that Carl Zeiss of Jena in East Germany made a 1000 millimetre reflector lens which was fast (f/5.6), light, compact, of very good resolution and available quite cheaply. It proved as good as the manufacturers said except for one snag: when the lenses were finally delivered around 1967 it was found that the resolution was spoilt by vibration, as the lens had not been designed for use with high speed cine cameras. But after many careful tests and modifications the Zeiss lenses provided the sharpest Woomera trials films yet seen from high magnification lenses.

The EMU vans were used until the late 1960s, by which time they were getting old. The housings on the back could not easily be transferred to another vehicle, and in any case there was not enough clearance to take the new overhung mount. The solution was to build a trailer light enough to be towed by a Land Rover, of which Ranges Group then had plenty. INS Group designed something suitable with a hinged roof, and a commercial trailer manufacturer built it. Three more followed of improved design, using a hydraulic rather than a geared mechanism to open the roof. Unfortunately they arrived too late to be used much, but at least they were kept after the end of the project and were employed on trials and exercises outside Woomera.

Posts further out than about 10 kilometres from the rangehead needed a means of tracking smoother than was possible with the manual mounts, as lenses of higher magnification and thus of smaller field of view had to be used. This was the reason for the servo-controlled powered mounts that appeared on Range E in the mid-1950s, usually sited with the Contraves and used in interception trials.

We have already seen how development work on an experimental tracking camera known as OTER started in 1952 in an attempt to measure miss distance and missile attitude at interception. Work continued for a while on OTER as a behaviour camera, but it was then dropped, mainly because of problems with the 70 millimetre film transport. But while OTER

Far left: 'IOTER', an early WRE servo-controlled powered mount for long distance photography.

Left: A Gooney-Bird mount with 4000 mm reflector lens.

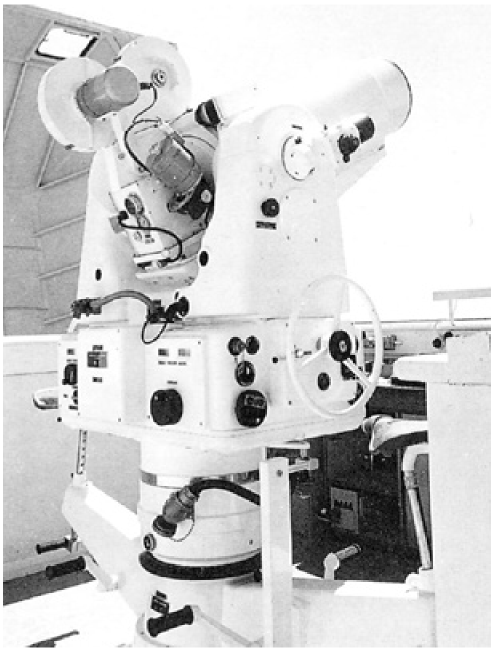
languished, an interim version (IOTER) prospered for a while. This used existing components where possible, including the proven Vinten camera and a mount adapted from a war disposals Sperry 1.5 metre searchlight mount whose tracking rate was controlled by servo systems. Like the Contraves kinetheodolite, all versions of IOTER needed two operators.

Optical Group did all the work on IOTER with drafting and workshops help from Engineering Wing. But a rival system had been emerging since 1953, when the newly formed Missile Instrumentation Group decided to employ the talents of their optical and radar sections in devising a servo-tracking mount of their own. After some preliminary experiments they decided in 1954 to take the aerial dish off a surplus No. 3 Mk 7 radar mount and replace it with a Vinten camera on an open frame. In the final design, a single operator tracked the missile while sighting through binoculars attached to the camera, and was carried around with the mount on a wheeled chair running on a circular bearing plate. The operator tracked in both azimuth and elevation with a small joystick connected to a rate-aided servo system. Tracking was smooth enough to use the high magnification lenses, up to 4000 millimetres in focal length, that were needed. The new design was officially a SAVU (Servo Assisted Vinten Unit), but colloquially a Gooney-Bird.[11]

The Gooney-Bird and the servo version of IOTER were both used at Woomera in the mid-1950s and there was friendly competition between their sponsors. In the end the Gooney-Bird won. Its tracking performance was superior and it could take more camera-lens combinations; most important of all it needed only one operator. By the late 1950s all the IOTERs had been supplanted by four Gooney-Birds, each built into a box-like van with a motorised hinged roof. Three of them were sited at Contraves posts K9-K10, K11-K12 and K15-K16 where the vans perched at the top of the mound, nestling close to the larger Contraves building as if afraid of falling over the edge. The fourth (V28) had a mound all to itself, one prepared for a twin Contraves but never so used. They were fitted with reflector (mirror) lenses that looked rather like small astronomical telescopes, as refractor lenses would have been far too long and heavy for the mounts.

The two other servo-tracking behaviour cameras on Range E were the only ones designed and built outside WRE. Basically they were a modified Contraves in which the firm had replaced the whole optical section with a Vinten camera and a Cox-Hargreaves 4000 millimetre refractor lens. This hybrid was called a Rakimo, after 'Rate Aided KIne MOunt'. Like the down-range kinetheodolites the Rakimos were obtained for the long range Bloodhound Mk 2 trials, and in 1962 they were placed at the two most distant Contraves sites (K27-K28 and K29-K30). Acquisition was provided for the Rakimos, as it was considered essential at these distant sites.[12]

The last development work on the servo-tracking cameras was a large mobile trailer to carry a Rakimo, and hence inevitably called a Rakimobile. The trailer was built for the Black Arrow satellite launcher and sited at a down-range optical site near Andamooka. Engineering Wing designed it to Miller's specification, which laid down that the instrument must ride as comfortably as a passenger in a car, and so the Rakimobile was given the wheels and suspension from the current Holden model. But when the Rakimobile returned from its first mild road test it was sitting much lower than when it left, and on looking underneath it was clear that all the coil springs had given up and sagged down to their rubber stops. They were replaced by sturdier truck components in time for the final Black Arrow flight, but for the earlier trials the whole Rakimobile had to be carried to Andamooka on a flat top truck, cushioned by air bags.



Right: One of the two Contraves 'Rakimo' mounts.

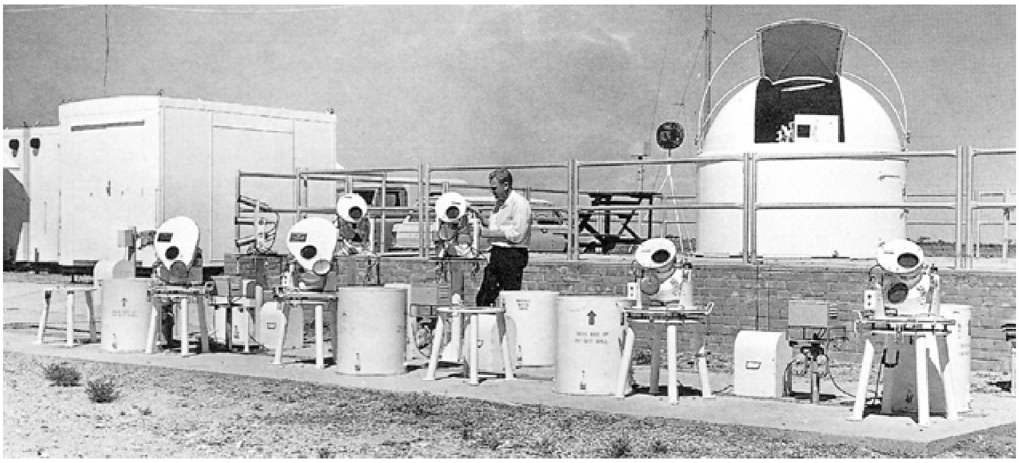
Far right: The Rakimobile trailer being prepared at Salisbury.

The mid-1970s saw the last of the interception trials for which the servo camera mounts had been developed. The two Rakimos and the Rakimobile were retained, but the older Gooney-Birds and their vans were sold off.

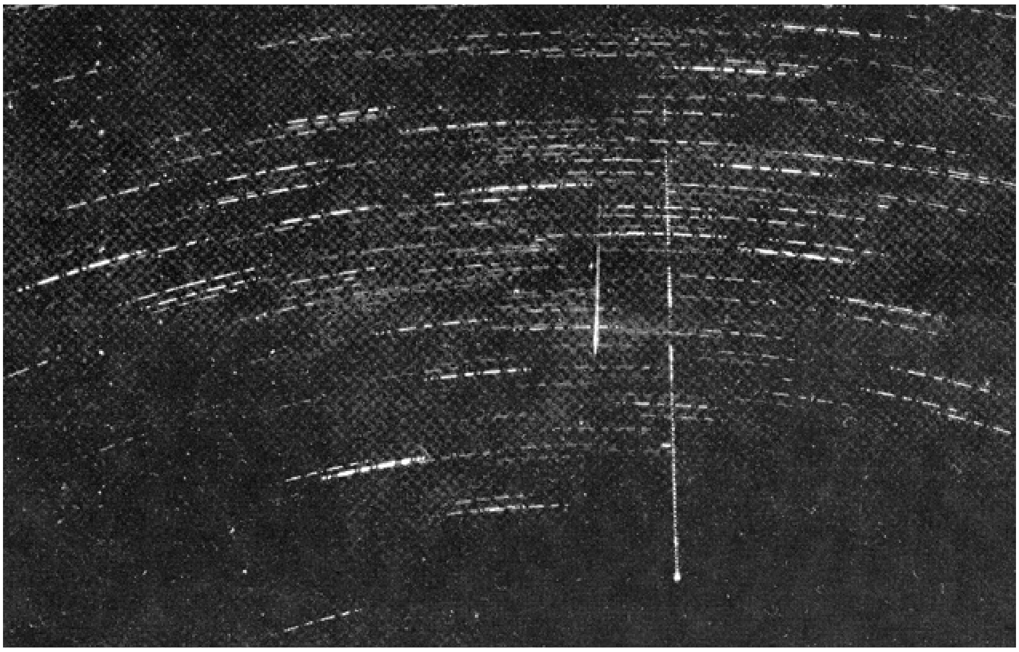
BALLISTIC CAMERAS

The most precise measurements of trajectory available on the Range came from a widespread network of ballistic cameras, first installed for the Black Knight re-entry test vehicle. They were often used as the standard against which the other systems—Contraves, doppler and FPS-16 radars—were assessed.[13]

Looking at a KF3 ballistic camera after a Contraves kinetheodolite, one would find it hard to credit that the former was the more accurate instrument. The KF3 was little more than a simple solidly made box camera exposing a single old-fashioned glass plate. Although heavy for its relatively small size, one man could pick it up. It had one moderate sized lens, an electrically operated capping shutter and some internal fiducial markers. It had no tracking mount but fixed its unblinking gaze on all the sky in its wide field of view, which was 40 degrees for the KF3. The secret of its great accuracy was that it was star calibrated each time it was used. The angular positions of images on the plate were measured relative to the very accurately known positions of the brighter fixed stars within its field of view.[14] Simultaneous pictures taken by two widely separated cameras gave the position of the object by triangulation. The ballistic camera system at Woomera was set up to measure



Ballistic camera site C19 at Parakylia. In the front row are four KF3 cameras, the two on the left with chopping shutters. A Wild BC4 is in the astrodome on the platform.



Part of a KF3 ballistic camera record of a Black Knight re entry. The vertical trails produced by the head (*left*) and body have been chopped by the KF3 shutter. The broken horizontal star trails are used for precise calibration.

trajectories at very high altitudes, so the base lines were as long as 145 kilometres. Had the Blue Streak project survived they would have been much longer than that, with additional sites spread around the continent from Ceduna on the Great Australian Bight, Talgarno on the shores of the Indian Ocean, and Oodnadatta near the Northern Territory border.

Despite their unsurpassed accuracy and simplicity, ballistic cameras never challenged the Contraves as the prime range system for trajectory measurement. They were inflexible instruments that would only work on a moonless, cloudless night after astro-twilight, meaning sufficiently long after dusk for the rocket and the higher levels of the atmosphere not to be illuminated by the rays of the setting sun. At any other time the plate would have been hopelessly fogged, since the camera was designed to expose one plate several times, or take one long exposure of a repeatedly flashing source.[15] The lengthy calibration was an additional drawback. It demanded a clear and very dark sky, yet for full accuracy it had to be done shortly after the trial. So twilight, moonrise and moonset times and cloud forecasts all had to be studied closely beforehand. Finally, extracting the data afterwards at Salisbury was a long and tedious affair which was never satisfactorily automated.

For the prolonged work with the Black Knight rocket—there were seven years of flights—arrays of ballistic cameras were set up on three sites to record the ascent: at Technical Area (C17), Coondambo (C18) and Parakylia (C19). One procedure, adopted for some early Black Knight trials, was to record its rocket flame until all- burnt, using KF3 cameras fitted with synchronised rotating 'chopping' shutters to give breaks that could be measured and timed in the otherwise continuous trail image of its flame. To extend this trajectory measurement after all-burnt, most Black Knights emitted high intensity flashes, timed on the ground by photo-electric detectors. Ballistic cameras without chopping shutters photographed these flashes during a single long exposure. As well as the KF3, the even more precise Wild BC4 camera was used for this, and both cameras were capable of extraordinary accuracy. They could fix the exact position of an object half a kilometre away within the width of a pea; or, more usefully, the position of a Black Knight 70 kilometres distant to within 1 metre.[16] The spectacular re-entry of Black Knight was recorded by KF3 ballistic cameras with chopping shutters at C18 and C19 and also at Mirikata (C36).

Calibration followed right after the trial, and continued for an hour or longer into the night. Without disturbing the camera settings, all the capping shutters were opened and closed in a preset sequence. This gave identifiable irregular breaks in the curved lines of light produced by the star images as they trailed across the plate with the earth's rotation, with corresponding timing marks on a chronograph. Back at Salisbury the Computers had to pore over the developed plates, identify individual stars from the trail patterns and use them to calibrate the whole plate. It was a necessary but tedious operation, even though the Zeiss comparator they used to measure star images was fitted with Ferranti digital read-out equipment to feed the readings into the IBM 7090 computer.

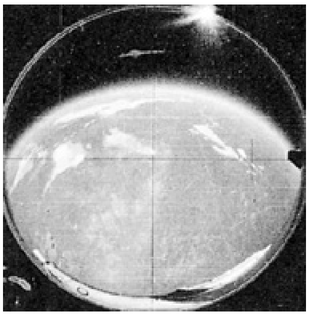
Most of the ballistic cameras used at Range E were designed and built at WRE by OMI Group. By 1965 there were forty-two of the KF series in place, all of them using the Kodak Aero-Ektar 180-millimetre f/2.5 lenses, selected because of their very good image quality. WRE also built most of the associated equipment which went into a large van parked at each site. Inside were racks of electronic gear to activate shutters in a predetermined sequence and to record to a millisecond the shutter times. Time recording was done on a chronograph of the same design as the old Moran-Frost Mk 4 unit developed for Range A in the early 1950s.

After the last Black Knight trial in 1965 the ballistic cameras were used only for occasional upper atmosphere work using Skylarks equipped with grenades. Before the project ended all the sites had been cleared and the equipment disposed of, except for four BC4 and fifteen KF3 cameras for which it was thought uses might be found in the future.

TARGET AIRCRAFT CAMERAS

We have seen that the attempt to measure 'on the ground' the vector miss distance in interception trials led by a devious route to the Contraves kinetheodolites and via OTER and IOTER to the Gooney-Birds. But there was another line of attack. Within a few years WRE came up with a remarkable pod camera, WRETAR, small enough to fit into a target aircraft. Its 186-degree fish-eye lens was even more remarkable for the period, and was the basis of a whole family of tiny recoverable cameras installed into the missiles themselves.

Recording an interception at close range from the target has obvious advantages.[17] High angular accuracy, essential from the ground, is unnecessary and thus cine cameras can be employed so long as they have a wide field of view. If this covers a full 360 degrees the cameras can be fixed: providing they film while the missile approaches, passes and recedes, it has to be recorded by one camera in the array at least. If each camera is carefully aligned and its lens calibrated, one can measure the angles of the sight-lines relative to the target. Then if there are two camera arrays a known distance apart—the further the better—and all camera films are timed, the missile trajectory relative to the target is obtainable by triangulation, and from this the vector miss distance can be calculated easily. With a close interception one can, with more trouble, even measure the attitude of the missile in pitch and yaw angles.



A frame of an AMPOR target aircraft camera, used to record interception. Sight lines to the missile were measured by two angles, one radially from the frame centre and the other like a compass direction.

This was the theory behind the pod camera system known as AMPOR (Airborne Missile Proximity Optical Recorder) which could measure miss distance with an accuracy of 2 per cent. AMPOR was first developed by RAE, which was why Australia concentrated initially on ground systems to avoid duplicated effort. RAE's first system was based on the GW1 cine camera, a rather bulky unit with a wide- angle 142 degree lens. For these cameras RAE developed a pod to fit on to each wing tip of the pilotless Meteor aircraft which were then being prepared as targets for the early interception trials at Woomera. No fewer than four cameras had to fit into each pod to give a completely spherical coverage of the sky.

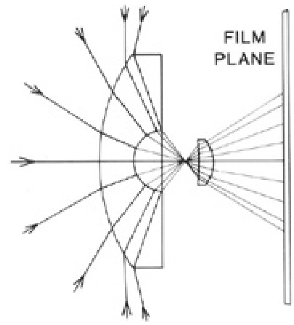
Bonnell's Optical Group first got involved with AMPOR in 1953, when the Government Aircraft Factory (GAF) was designing wing tip pods for Jindivik. The RAE pods suited the Meteor but were rather large for the smaller Jindivik, and the problem was exacerbated the following year when RAE swapped the GW1 camera for the GW2 in order to double the recording time from 6 to 12 seconds. The new array needed an even bigger pod, and GAF baulked at fitting that to the wings of Jindivik: the drag and weight would have been too much. GAF itself produced a slightly smaller pod which Jindivik could just handle, but it was still far from ideal.[18] Bonnell recognised that the problem could be solved if he had lenses with a field of view a little more than 180 degrees, so that two cameras facing in opposite directions would then cover the full sphere, with a little overlap. A smaller and aerodynamically cleaner pod would then be possible. No suitable lenses could be found on the market, but he was keen to try to develop one. In early 1953 he put one of his sections on to the problem, and by late the following year it had produced one with a remarkable 240 degree view. But it was a rather complex composite lens, with the peculiarity that the image of anything moving across its view would suddenly jump and reverse direction as it entered and left the central part.

Frank Dixon, the recent graduate who developed a novel ultra-wide-angle lens for AMPOR.

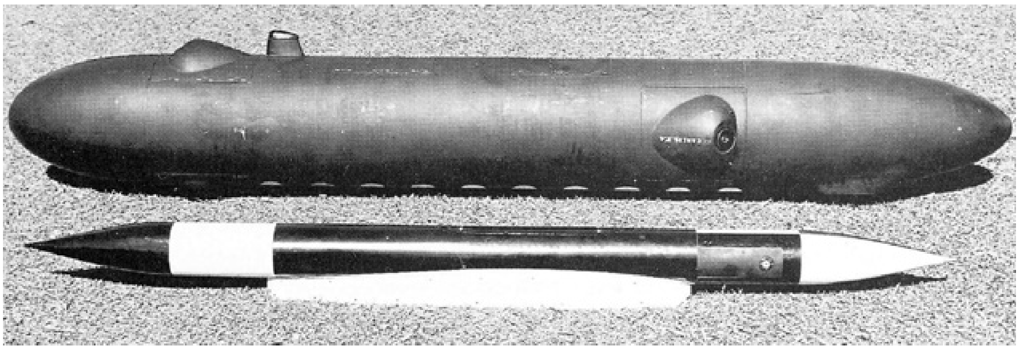
A young new graduate, Frank Dixon, had just joined Optical Group. Although nobody asked him to do so and he had little practical experience in lens design, he worked away on an idea for a wide-angle lens, quietly at first until he was confident of being on the right track. Before long he had succeeded in developing a simpler but very effective lens. It had a field of view of 186 degrees, less than the composite lens, but quite enough. What was more, it was more compact and cheaper to make: the latter was important as each Jindivik was not expected to last more than five sorties. Its special value was that equal radial angles in space in front of the lens gave equal radial distances (measured out from the centre) on the flat film. This naturally distorted the image, especially at the edges, but it was ideal for measuring angles, which was the whole purpose of the lens.

While the Dixon ultra-wide angle lens was being designed, Bonnell was busy developing a camera and GAF a new pod to exploit its potential. The result, achieved by shaping the camera to fit the pod rather than the reverse, was a light very slim pod without any protruding blisters and only 14 centimetres in diameter, less than half the size of the former pod. Two of the new cameras went end to end into the pod, with the front one looking up from the pod nose and the rear one looking down to cover the lower hemisphere.[19] The new 35 millimetre 100 frames/sec camera was later named WRETAR (WRE Target Aircraft Recorder).[20] Apart from its shape, it was accurate, reliable, simple to set up, robust enough to safeguard its precious records in a crash, and yet cheap to produce. WRETAR had the great advantage that its larger field of view simplified data reduction. Many interceptions now appeared on the film from just one camera instead of perhaps three or even four, avoiding the need to transfer readings via the overlap area to the other record. Another advantage was that four WRETAR cameras would run from the aircraft power supply. Previously power had come from lead-acid batteries in the pods, which made recovering the cameras after a crash a messy business.

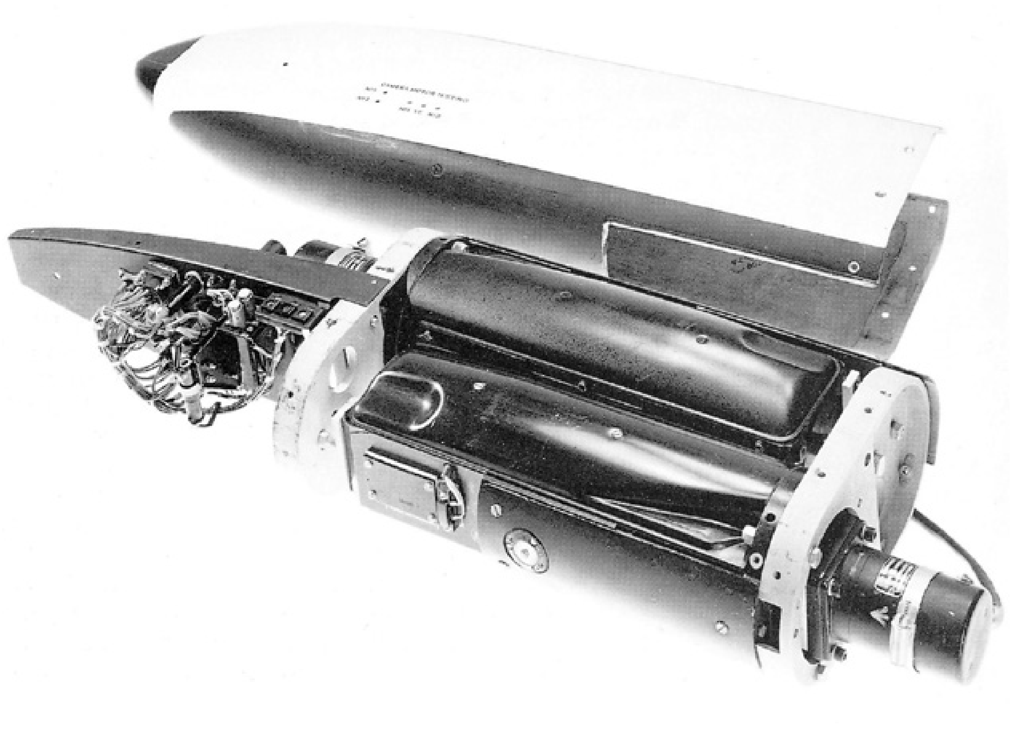
The prototypes of WRETAR were developed by Fairey Aviation at Salisbury and flight tested in 1957. Fairey then undertook the initial production run of 192 cameras. The following



The 186-degree field of view of the WRE ultra-wide-angle lens.



A 14-centimetre diameter pod alongside the old 38-centimetre pod designed for GW2 cameras.



Two WRETAR cameras mounted back to back, in a pod designed for high altitude Jindiviks.

year the first WRETAR-equipped Jindivik entered service and, as the targets with the old GW2 cameras crashed or were destroyed, the system gradually became universal. WRETARs were also fitted to the Meteor targets in another kind of pod and buried in the wings of the pilotless Canberra bombers. Later still a new pod was designed for the extended wings of the high altitude version of Jindivik, in which the cameras were mounted back to back and forward of the leading edge of the wing. WRETAR shared in the general export success of the Jindivik target. Of the 2500 or so cameras built to date, several hundred accompanied the Jindiviks sold to Britain, Sweden and the US Navy, and WRETARs are still being used with the aircraft, measuring miss distances on opposite sides of the globe at Aberporth and Jervis Bay.

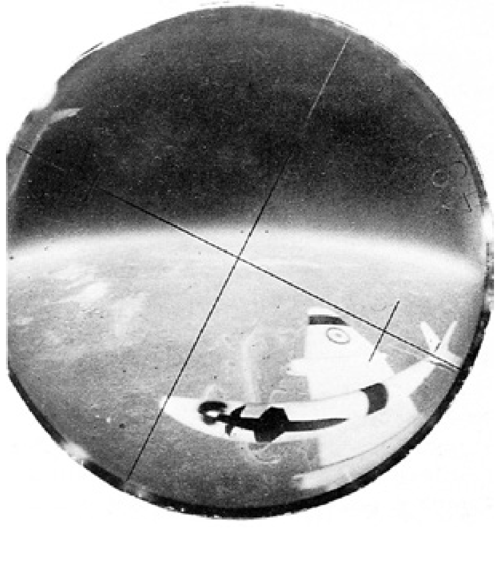
MISSILE CAMERAS

Small recoverable cameras were installed in missiles at Woomera at an early date: in 1952 cameras were mounted in the forward section of RTV1 rounds, and at least two were recovered intact after the flight. They had pointed to the rear, and produced good pictures of the boosts separating. The cameras were small 16-millimetre GSAP (Gun Sight Aiming Point) cameras, used in the war to record the effectiveness of fighter aircraft guns in combat. At the time the American Bell and Howell GSAP was the only small camera readily available for the purpose. Ray Barnes of Optical Group worked on this task, and recalls how he came up with one clever expedient:

> I got several of these GSAPs, ones that worked well in the centrifuge, and mounted them up with long screws in a steel box that would survive a fall from 20 000 feet. But how to cushion the cameras was the problem and what I did eventually was pack them in dry rice. It acts almost like a fluid under extreme pressure. I got the idea from reading a book about Wingate in Burma—how they had their supplies dropped and their eggs were packed in tins full of dry rice and very, very few of them broke. It seemed to work quite well.[21]

Murray Ziesing

WRETAR's fish-eye lens had an obvious application in missile cameras, since it allowed just two small cameras to photograph everything visible in a complete sphere round the missile. One of the first systems to use it was WRECISS (WRE Camera Interception Single Shot) developed by Bonnell and Murray Ziesing in 1957 with much help from John Nelson, a talented design draftsman who also worked on several later missile cameras. WRECISS was not a cine camera like WRETAR but exposed a single circular piece of film. The instant of exposure was when the proximity fuze of the missile signalled the closest approach to the target, and was therefore the moment when the warhead would have detonated, had one been fitted. As warheads are directional in their effect it was important to know at such a moment the relative attitude, distance and direction of the target.[22] WRECISS provided this information with an accuracy of about 2 degrees. It was a very tough camera, being machined out of solid steel, but the shutter had to be engineered carefully. It had to be very robust and yet open and close within a millisecond or so of fuze operation, as warheads detonate very quickly. An electrical puffer, a small explosive device used in fuze trains, proved most



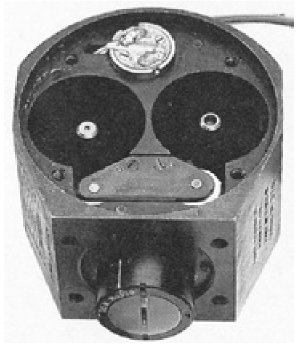
Right: WRECISS, the small recoverable missile camera using the ultra-wide-angle Dixon lens.

Far right: A remarkable WRECISS record recovered from a Thunderbird missile, showing its own shadow on the Canberra target at interception.

effective, operating the shutter in about half a millisecond. When Bonnell was explaining WRECISS to visiting service officers, he liked to demonstrate its operation by firing the puffer. The loud bang aided the concentration of any who might have been dozing off.

WRECISS was first used on interception trials in 1958 and later became a standard fitment on most of the first and second generation missiles: Bloodhound Mk 1 and Mk 2, Thunderbird Mk 1 and Mk 2, Red Top and Seaslug. in 1960 two pairs of cameras were fitted into Seaslugs for twin target trials and were operated by successive fuze pulses. Although WRECISS was small enough to fit in most missiles, a special miniature version was developed for Sea Dart.

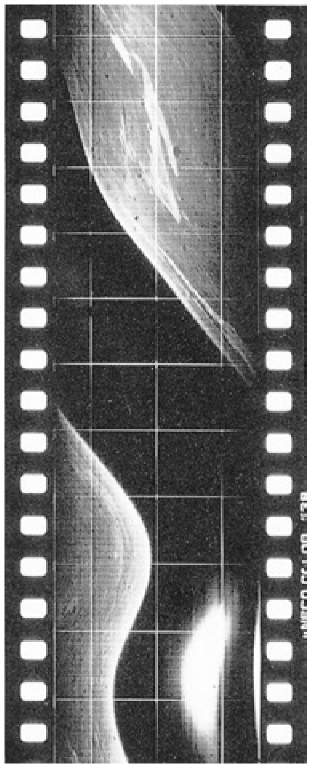
A missile camera working on a different principle was WREROC (WRE Roll Orientation Camera). Measuring a missile's roll in flight was important for those which used the 'twist and steer' principle like Bloodhound, and yet it was difficult to accomplish. Roll telemetry was not very accurate, and, though ground-based behaviour cameras could record roll by photographing a pair of fin-tip flares from the rear, they could not resolve the two flares at longer ranges. Furthermore, flares often had an adverse effect on performance. WREROC was a recording, but not a cine camera, it used a fish-eye lens, but one with a mask with a horizontal slit in front of it, so that the image which formed on the constantly moving film was a thin band. The image showed the varying position of the horizon as the missile rolled round its long axis. Timing marks were also photographed on the film, making it in effect a graph of roll angle against time. Usually two WREROCs were fitted to look in opposite directions at both horizons, so their angular separations could be checked to make sure that spurious horizons such as distant low clouds were not being measured. WREROC came in two versions: one to fit externally and one internally with only the lens protruding. During an early trial in 1960 with an internal camera, the missile malfunctioned and dived into the ground at supersonic speed, burying itself and the WREROC records 6 metres deep. As the records were important the two battered cameras were exhumed and technical assistant Joe Mellon took them and a hacksaw into the dark room. He emerged hours later with two developed colour films, good enough to help diagnose the wayward roll behaviour of the missile.



The WREROC slit camera.

The last type of missile camera using Dixon's wide-angle lens was WREMARC (WRE Missile Attitude Recording Camera). It was a WREROC of the external type fitted with an unmasked lens and turned into a slow cine camera running at only 10 frames per second. By measuring the angles of the horizon and of known ground features appearing on the film, one could work backwards and compute by how many degrees the missile was pitching, yawing and rolling at the time of each exposure. For some trials, notably those of Sea Dart, it was paired with another very similar type of camera, WRESLAC (WRE Sight Line Angle Camera) which recorded the angular direction of the target as seen from the missile.

All these missile cameras fell into disuse after the last Sea Dart interception trial in 1974. In their day they were important tools in the development of the British guided weapons: each one was designed to do one job and do it well, and each was the product of the countless hours of labour required to turn a concept into an instrument capable of withstanding the enormous forces imposed by a missile in flight.



A WREROC record of missile roll.

FILM PROCESSING

Woomera's optical instruments produced great quantities of exposed film, which poured not only from the many and various cameras but also from the telemetry system and in the early years from the doppler and MTS recorders too. A single trial might produce 5 kilometres or so of 35 millimetre cine film. All of it had to be developed and printed at top speed as the results were always wanted urgently; yet the films represented a large investment when they were the records of an expensive trial. Many of them were secret. Thus one early decision was that films would be processed at Salisbury.

At first the dark room facilities were very crude, partly because of shortages of materials just after the war. In fact the first deep developing tanks, used in 1948-49 to process records of early parachute trials, were made out of New Zealand kauri timber that happened to be in stock, rather than the more usual weldable stainless steel. In the 'rack and tank' method used then (and for many years thereafter for short lengths of film), the films were wound around flat wooden racks and then immersed in turn in deep tanks holding developer, fixer and wash water. Longer films were wrapped around an open 'squirrel cage' spool and rotated slowly in a tank shaped like a horse trough. Work would go on far into the night until processing was complete, and by then most of the workers would be wet through—they usually wore shorts. Frequently Boswell would drop in about 1 p.m. from his nearby home in Penfield Avenue, bringing cheer in the form of beer, sandwiches and encouraging words. By the morning the films were ready for the Computers to read.[23] Another onerous task was processing the 35 millimetre films from the Vinten HS300 cameras, which usually ran at high speed and used a full 120 metre magazine of film. Ron Edmondson recalls how he would laboriously interwind each film with Correx edge dimpled apron (to allow developer to get to the film) then dunk them up and down three spools at a time, in tanks—first water then developer, water again, fixer—all in total darkness, before putting them into the final wash water. Afterwards the film was wound off on a large rotating drum and dried by infra-red lamps.[24]

Ray Barnes in the Range E film drying van, before the fire.

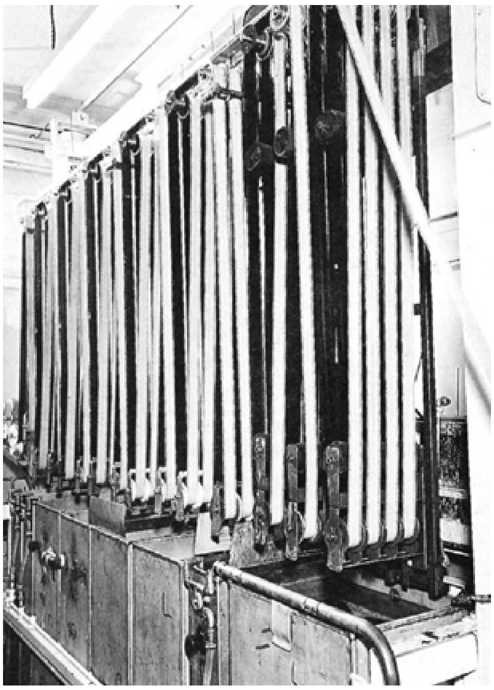
Little film was processed at Woomera, except for 'quick-look' records and test strips to check the instruments or investigate faults. At first the processing was done in the village by RAAF photographers in mobile vans, but when Range E opened Optical Group fitted out two trailer vans and moved them there in time for the first campaign, the 1951 Fairey VTO trials. The vans were cramped and had no air- conditioning, but Ray Barnes remembers a lighter side:

> We had a darkroom clock with an alarm set for three minutes of processing time, but there was no way of resetting the clock in the dark. We'd found that you could sing the three verses of the 'Gendarmes' Duet' in exactly three minutes . . . you wound up the film on to your rack and put it into the developer and started singing and by the time you'd finished it your films were done and you could move them over into the wash tank and the fixing tank. People often wondered why there was this great mixed chorus of raucous voices singing the 'Gendarmes' Duet' inside the processing vans.[25]

The second van was equipped with large heaters and blowers for drying film. One day the highly flammable nitrate film still used at the time burst into flame and a complete set of trials records was lost; the van survived but was not used again for drying. In 1953 the processing facilities were moved to the new Instrumentation Building nearby.

At Salisbury it had always been recognised that processing trials films manually was very labour intensive and gave inconsistent results, so the use of continuous processing machines was an inevitable step. In 1949 Hugh Brophy of Optical Group designed a machine for processing 35 millimetre black and white cine film chiefly from the Vintens, but for various reasons including lack of space it was not used until 1954, when it started to process not the original negatives but print films made from them. For negatives a small continuous processor originally intended for Woomera was pressed into service, and with the great surge in trials after 1955 the number of such 35 millimetre processors grew eventually to

Hugh Brophy.



Right: One of the WRE continuous processing machines for 35 millimetre black and white cine film.

Far right: The colour processing machine used in the 1970s.

five.[26] In these machines the exposed films were spliced together one by one, fed through developing, fixing and washing tanks, then dried and taken up on large spools. Another commercial Houston-Fearless machine processed 16 millimetre cine film. In the early 1960s a British Photomec continuous processor was installed for wide films, particularly the 337 millimetre records that were shortly to roll out from the Salisbury telemetry replay station. A decade later a continuous colour processor was added. Previously all colour films had been sent interstate for processing. The delay mattered little when the colour films were for publicity or documentary purposes, but now Vinten colour films of a new series of 'get well' trials of the old Seaslug guided weapon had to be processed as soon as possible, so that problems with boost separation could be resolved quickly. Colour was not used for aesthetic reasons but because it supplied an extra channel of information; for example, it distinguished flame from smoke in a rocket efflux, or it identified boost motors painted different colours in a freely rolling missile.

Continuous 16 millimetre and 35 millimetre contact printers were used to print all cine films, including colour films. There was also a Photomec wide film printer. All were commercial printers and most were far from modern, particularly the old Bell and Howell model J printers, which had been ordered in 1950. Nevertheless they proved adequate.

Not all processing was by continuous machine. Some of the old manual facilities were retained, such as the deep tanks used to handle short lengths, and film gauges that would not fit the machines, including the old 'twenty-four by thirty' (610 x 760 millimetre) telemetry records. Special tanks were used for ballistic camera plates.

The film processing laboratory was staffed by a team of specialists, under supervisor V. V. Zeleny from 1959. Vic Zeleny was a colourful Czech from Prague, who at the height of the cold war had quietly walked out on his pharmacy business and everything else and headed for the West. The activity in Zeleny's lab was often frantic, with everyone wanting to see their records at once, particularly if things had gone badly. Yet slipshod work was intolerable, because a lost or damaged film might wreck the labours of dozens of staff and render futile an expensive trial. Accordingly quality control and accounting were critical. Films had to be properly logged and inspected after processing, and negatives graded before printing. There was full quality control of all processing, with frequent sensitometric tests. Finally the finished prints had to be assessed while projecting them in the theatrette, so that any instrumentation faults could be caught before they could harm later records. Only then could the prints be handed on for data reduction or sent to the Range users.

Vic Zeleny.

All this activity came to an end during the final run-down. The film processing service closed completely and all the equipment was sold off. Worst hit of all were the staff. The film processors had had a specialised job, and only one or two other openings could be found for them elsewhere in WRE. Some retired and a few resigned, but most had to face transfer to other departments where they usually did quite different work, and several took a cut in salary. No group was worse affected by the close of the project than the film processors.

OPTICAL RESEARCH

To make best use of the various optical systems, much supporting scientific research was carried out at Salisbury, particularly in the years between 1955 and 1968; and not surprisingly, given the concerns of the Range, the main theme was an investigation into the many factors which affect the quality of photographic images. The work was shared between Frank Dixon and others in Optical Group and Dr Peter Crosby and his section of OMI Group. A great deal of this research was published both internally and in the open literature.

Most of the photographic recording at Woomera was over long distances using high magnifications. Under these conditions two factors causing degradation and inaccuracy of the image are shimmer or 'seeing' and mirages arising from changes in light refraction through differently heated layers of air, especially near the ground. The progress made by Dixon and his staff in measuring and predicting these effects and in finding ways to minimise them was mentioned earlier. A third atmospheric effect, the scattering and absorption of light by airborne particles of dust, was studied by Crosby. He and Koerber developed a number of nephelometers (from the Greek *nephos*: cloud) as measuring instruments, and concluded that in Woomera's normally transparent air visibility was a relatively minor problem. They also studied the likely contrast of various objects against the background sky

Dr Peter Crosby.

Dr David Gambling.

at various times. The other optical factors studied by Optical Group were those bearing on the camera system: the performance of lenses, including the effects of heat and vibration, and the characteristics of different films.

The culmination of all these investigations was an advanced mathematical model by David Gambling, which aimed to describe the effect of all these factors working in unison on the visibility of a distant object of known shape and contrast against the background sky. The computer model was validated by practical measurements, but by that time the first contraction of 1968 had removed most of the purely scientific effort from the joint project, and Gambling's model was only used by the project in a computer program by Owen Scott of INS Group, which offered predictions of how optical systems would perform under given trials conditions. Unfortunately this was shortly before the final run-down of the Range. Nevertheless, the earlier work had practical benefits in its day when it came to such matters as scheduling trials, designing Contraves towers and the routine focusing of lenses.

Notes and Sources

1. Note dated 31 October 1946 by W. A. S. Butement. File SA5010. In the event, radars and all other tracking instruments at Woomera used the normal and simpler 'altazimuth' mount. Those down-range were always placed to one side of the centre line, not only to avoid tracking through zenith but for safety reasons too. It is difficult to understand why placing the OPs directly on the centre line was favoured in 1946.
2. At one time or another nine separate ranges were used at Woomera, some of them for only one project, but all except Range E were closed by 1956. They were given the following letter codes:
   Range A—Bomb ballistics
   Range A1—Blue Boar guided bomb trials
   Range B—VT Fuze trials
   Range C—Parachute dropping area
   Range D—Photoflash dropping area—in Range A1 area Range E—Main missile range
   Range F—Interim missile range Range G—Short missile range
   Range G1—Anti-aircraft gunnery—on northern flank of Range G
   All instrumentation posts were given identifying codes, as were launchers and survey references. At Range E the codes started with a letter to show which system the post belonged to, as follows:
   A Tracking data
   B Spectrographic and radiometric equipment
   C Ballistic cameras
   D Reflection doppler
   E Survey reference points
   FFlash detectors
   HAcoustic equipments
   KKinetheodolites
   LLaunchers M Telemetry
   PMissile Tracking System (MTS) R Radars
   S In-flight safety equipment
   T Transponder doppler
   U Timing, communications and hazardous services
   VTracking behaviour cameras
   VLFixed behaviour cameras (launcher cameras)
   X MTS optical trackers
   The letter code was usually followed by a number to identify the particular post in that system, e.g. the radar posts were Rl, R2 etc. Sometimes more complicated codes were used, such as DA1-R (reflection doppler, rear station no. 1, receiver) or C18 F2 (flash detector at ballistic camera post C18). All post codes were recorded in a Range Register, which also showed its precise surveyed co-ordinates and brief details of the instrument. The major instrumentation sites were often given place names, and this saved confusion when there were posts belonging to different systems sharing the same site, such as at Mirikata and Parakylia.
3. Ivan Southall, *Woomera*, Angus & Robertson, Melbourne, 1962, pp. 129-30.
4. Bonnell's Group had many changes of name during its long life. Originally 'Optical Apparatus', it was renamed in turn 'Optical', 'Optics and Servomechanisms', 'Mechanical and Optical Techniques' (the name it bore when it left the joint project in 1968) and more recently Optical

Techniques. Bonnell remained its leader until after 1968. For simplicity here it is always referred to as 'Optical Group' or 'Bonnell's Optical Group'.

5. Mornings were usually clearer than afternoons. At 8.30 a.m. the sky was essentially cloudless on an average of 59% of occasions taken over the whole year. By 2.30 p.m. the probability of this dropped to 46%. (Statistics taken from a WRE handbook *Geophysical and Meteorological Data of Woomera Ranges* edited by Bryan Rofe.)
6. Similar manual tracking was employed in the Askania rangefinder used during World War I to track slow Allied medium altitude bombers. In the previous war naval rangefinders by the same firm had been installed in the German capital ships that caused severe losses to the Royal Navy at Coronel and Jutland. Experience with design and production of these devices of outstanding accuracy and workmanship led to the early (1937) KTh 37 model kinetheodolites. This and the later KTh 41 model were very probably used to track V2s at Peenemünde. When that base was evacuated in February 1945 the many KTh 41 kinetheodolites held there were sent back to the Askania factory in Berlin for overhaul. This is where the British troops captured them in May 1945. B. S. Kervell, Curator of the RAE Museum, contributed this information, adding, 'the Askania kinetheodolite for many years appeared to represent the apotheosis of optical and mechanical perfection, so much so that those working with them or on them were subject to the emotions of little boys who had received the most perfect present that Father Christmas could ever bring. Grown men crooned over them or were heard talking to them . . . Definitely they possessed design limitations which were discovered and circumvented partially, but for their era the most advanced versions had no peer. Their cost was phenomenal in real terms and illustrates the lavish resources allocated to the V2.' (Contribution of 17 September 1986).
7. Southall, p. 130.
8. LRWE's original specification called for a choice of 20 and 40 frames/sec. Contraves achieved this, but running at the higher speed produced registration and synchronisation problems. Eventually the gearing was modified to run at 10 or 20 frames/sec.
9. LRWE Progress Report No 15 as at 30 June 1954, pp. 2, 13.
10. Reminiscence of Ron Nicholson at an interview in August 1985.
11. Named after a similar early camera mount developed at the US White Sands range, apparently so named because it resembled a bird sitting on a nest.
12. The Rakimos were primarily to measure attitude of Bloodhound Mk 2 in flight. Rakimos were preferred to making more Gooney-Birds as better accuracy was expected. Another attraction was that many parts were interchangeable with Contraves kinetheodolites and at one stage replacement of all the Gooney-Birds by Rakimos was contemplated.
13. Ballistic cameras were so named because they were first used to measure ballistic trajectories. The Ballistic Research Laboratories were pioneers in this field in the USA. In the early 1950s the BC-37 ballistic camera system was developed and used at the Eastern Test Range, until replaced by the Wild BC4. E. H. Ehling (ed), *Range Instrumentation*, Prentice Hall, Englewood Cliffs NJ, 1967.
14. The measured angular accuracy of the KF3 was ten seconds of arc, while for the even more accurate Wild BC4 used as a ballistic camera, it was three seconds of arc, i.e. 1.5 metres in 100 kilometres. The errors were considered to be random only, the systematic errors being negligible by comparison.
15. To be quite accurate, there were experiments in the 1950s with special shutters, tracking slits and filters in order to use ballistic cameras in daytime, but they came to nothing. Further, there were a few daytime Skylark grenade trials around 1959-60, in which the grenade bursts were sensed by flash detectors which triggered fast-acting electric shutters on special ballistic cameras, in time to record the remainder of the flash before closing again. These cameras were developed by University College London, the sponsors of the particular Skylark experiment.
16. Strictly speaking the BC4 was not a ballistic camera but a phototheodolite, which is a surveyor's theodolite equipped with a plate camera. Wild, the Swiss maker, designed the BC4 specifically for astrographic work. At Woomera the intention was to use the BC4 as a theodolite, which meant carefully levelling it and orienting it and reading off its scales precisely by eye to within a fraction of a second of arc. But because the range operators were not trained surveyors the BC4s were eventually not used in this way. Instead they were star-calibrated like the KF3s, using an external shutter added by WRE. Their main advantage over the KF3s was that they were a little more accurate although with a smaller field of view, particularly for those BC4s in which the 210 millimetre f/4.2 Aviotar lenses originally fitted had been replaced by faster 300 millimetre f/2.6 Astrotar lenses. Both gave higher magnification and better quality than the 180 millimetre Aero-Ektar fitted to the KF3. The Astrotar had been specially designed to give sharp images of stars as well as for precise measurements.
17. The Contraves kinetheodolite network could not give acceptable accuracy for vector miss distance if interception were closer than about 30 metres, even if they were augmented by the Gooney-Birds.
18. Contribution by Joe Wood, formerly of Optical Group, written in 1981.

19. Another experimental version of the WRE target camera was designed so that the two cameras looked fore and aft through the nose and tail fairings of the pod rather than up and down. The UWA lens was mounted at one end of a tube, with another lens behind it to relay the image to the film at the other end of the tube. This 'long lens' version was never adopted.
20. The name AMPOR covered the whole miss distance recording system, including WRETAR cameras, pods, control and timing equipment and calibrating devices. Bonnell coined both terms.
21. Contribution by Raymond Barnes supplied in 1986.
22. While WRETAR records could be used to compute this information, WRECISS was more accurate, as the time was just right. Also the target gave a larger image on WRECISS, and a better defined shape for measuring attitude, than the missile image on WRETAR. As it was only practicable to fit one pair of WRECISS cameras to the missile, triangulation could not be used to derive vector miss distance, but it could be done another way if interception were reasonably close. Angles to recognisable widely separated points on the target image were measured, and knowing the shape of the target, its position and also its attitude relative to the missile could be worked out. Wire space models and model target aircraft were constructed to help in this. One could do even more with that single small WRECISS record. By measuring angles to the horizon, sun or known ground features the missile attitude relative to ground axes could be derived. The salt lakes in the Range area, such as Lake Hanson and Lake Younghusband, were easily recognisable ground features.
23. Nicholson interview.
24. Communication from R. Edmondson written in February 1986.
25. Barnes contribution.
26. Contribution from H. J, Brophy written in March 1986.

15 Instrumentation 2: *The Ears of the Range*

ELECTRONIC INSTRUMENTATION

During Range E's main period of growth from 1953 to about 1962, its instrumentation was divided for convenience into two classes: the optical systems of the previous chapter and 'electronic instrumentation. In this chapter we shall be speaking of radar, the Missile Tracking System (MTS), doppler and telemetry, all of which certainly belonged to this second class. The remaining systems—timing, sequencers, hazardous circuits, and voice, line and radio communications—were sometimes lumped in with electronic instrumentation and at other times were regarded as engineering services, not instrumentation at all.[1] These remaining systems are discussed in the next chapter.

The feature that distinguished radar, doppler, MTS and telemetry from optical systems was not that they were electronic but that they used radio waves instead of visible light to track or obtain data from airborne missiles, bombs and aircraft. Metaphorically speaking, these radio instruments were the ears of the Range. Since both radio waves and visible light are electromagnetic radiation the difference between them is only quantitative, but it is a marked difference nevertheless. The radio instruments used wavelengths from 1.5 metres down to 0.06 metres, whereas visible light has a wavelength of around 0.000 000 5 metres. Working on these vastly shorter wavelengths means optical instruments can provide much more sharply defined images than is possible with radio; and for some purposes, such as recording the appearance of missiles in flight, optical methods are indispensable. Optical tracking also works better at low elevation angles than radio tracking, which is susceptible to ground reflections and clutter.

But optical instruments have their limitations too. Visible light has little penetrative power, so in cloudy weather radio methods come into their own. Even in clear weather radio tracking is superior at longer ranges, particularly when a transponder[2] or radio beacon is fitted to the missile or aircraft. Good optical tracking in daylight demands a strong contrast

An AA No. 3 Mk 7 radar at Range G (1951).

between the sky and the object, and this can be poor and variable at long ranges. So optical tracking at very long distances was limited at Woomera to night trials of missiles fitted with some light source, be it exhaust flame, flares or electronic flashes.

The real-time tracking system was vital to the actual conduct of trials. Computers and automatic plotting tables fed by radar or the MTS displayed the precise position of trials aircraft at every moment, permitting them to be navigated from the ground. It also allowed the real-time tracking of missiles for safety surveillance. Often the data came from special optical trackers, but these were only relied on at low altitudes where radio tracking was uncertain.[3] At long ranges radar and the MTS were superior, but even at moderate ranges they had the advantage of tracking automatically once they had found their target. Thus they gave a more reliable real-time track than the manually pointed optical instruments.

The truth is that radio and optical instrumentation served complementary roles. Each had its strengths and weaknesses, so that both were used throughout the project—few trials relied solely on one or the other.

EARLY TRACKING RADAR

Radar had been developed during World War II by both sides as a powerful new tool for detecting and locating enemy targets, and so it was still relatively new when Woomera was founded. The principle is simple enough. A series of concentrated bursts of radio energy is directed at the target and the weak reflected signal picked up after a time delay. This delay is measured, and since radio waves travel a constant 300 metres in each millionth of a second, the delay gives the distance of the target. The position of the target in both azimuth and elevation can also be measured from the pointing angles of the highly directional radar aerial, which is designed to align itself to the strongest signal.

We have already seen in Chapter 10 that the first type of tracking radar to be used at Woomera—for bomb ballistics trials on Range A—was the British AA No. 3 Mk 7 set, the famous 'three mark seven' that dominated electronic tracking at Woomera in the first years. It was designed late in the war as a mobile S-band (10 centimetre wavelength) radar for controlling anti-aircraft guns. The enemy aircraft was tracked by a narrow beam aerial inside a dish reflector, mounted on the roof of a small van. Once the operator had sighted, or acquired, the echo on a screen, he could switch to 'lock on' to make the servo-controlled aerial follow the echo automatically. The No. 3 Mk 7 continuously fed to the gun predictors the polar coordinates of the aircraft being tracked: the predictors calculated the aiming angles of the gun and the time delay to set the shell fuzes. At Range A the No. 3 Mk 7 had a new role: tracking for aircraft navigation. Here the radar outputs were fed via converters and other devices to plotting tables, on which the position of the aircraft was displayed on a map of the Range.

After 1955 the No. 3 Mk 7 radars were used similarly at Range E, this time to navigate Jindivik and other targets as well as the manned aircraft used in air-to-air missile trials such as Blue Jay. The radars were also used in a minor way for trajectory recording, but with their poor accuracy only as a back-up to kinetheodolites and doppler. The No. 3 Mk 7 had no recorder built in, so LRWE added one in the early 1950s. On dials like a clock the changing co-ordinates of the aircraft were shown, and these dials were 'frozen' at intervals by flash lamps and photographed by a Cinetra continuous film camera.

The No. 3 Mk 7 radars tracked missiles as well as aircraft. Two of them had been set up in 1949 at the early Interim Missile Range to record the flight paths of the German Taifun rockets, and they were used in the same way for RTV1 trials at Range G and later at Range E. For these early missile trials the radars supported the doppler and Askania kinetheodolites—they were no match in accuracy and took much longer to lock on to the missile, but once on they usually stuck to their quarry long after the Askanias and doppler had lost track. When the Contraves kinetheodolites were introduced it was the radars that provided the acquisition service that enabled the Contraves operators to find the missile again if they lost it.

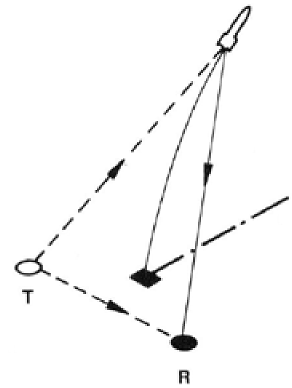
The No. 3 Mk 7 was the sole instrumentation radar at the Range until the new precision FPS-16 radars were installed in 1960.[4] The role of the No. 3 Mk 7s diminished with time as the network of MTS stations took over the role of target aircraft tracking, but they continued in use for many years. By 1960 there were three of them behind the launchers at

Range E and another down-range at Mt Eba. In fact they continued in use for short range trials well after the advent of the FPS-16s. They lasted until 1966 when the Army withdrew the small RAEME Radar Troop that had operated them since 1955. For nearly twenty years they had proved highly useful for navigating trials aircraft within their relatively short range and for helping other instruments acquire aircraft and missiles. They were mobile, plentiful and also economical: just one station operated by one man was enough to get a fix if it tracked successfully.

One problem with the No. 3 Mk 7 was its limited range. With the impending longer range second generation weapons looming in the late 1950s, ranges of over 100 kilometres would be likely. The radar was designed to work up to 32 kilometres, and though it proved a relatively simple matter to double or treble the range scale, this did not make it any more sensitive. The best solution was to fit a radar transponder to the object being tracked, and S-band transponders compatible with the radar were produced by WRE. Unfortunately they were too large to fit into most missiles, but some were fitted to target aircraft.

In the late 1950s a few spare radars were modified to measure wind structure at high altitudes, this information being needed for Skylark and Black Knight trials. The radars tracked meteorological hydrogen balloons which carried WRE-developed transponders. One of the wind-finding radars was installed at the Technical Area for the resident Meteorological Bureau section under George Trefry. Unfortunately Trefry lacked the staff to keep it running, and soon he had to resort to more traditional methods.

DOPPLER



The simple single station reflection doppler system used for the first LRWE missile firing in 1949.

Everybody has noticed the doppler effect: the rise in pitch as a moving sound source such as a train whistle or car horn approaches and then the fall as it recedes.[5] The effect is not confined to sound. Another example familiar to astronomers is the red shift phenomenon. The frequency of light arriving from distant stars and galaxies is found to be shifted down towards the lower or redder end of the spectrum because most of those bodies are receding relative to the earth.

Most missile ranges have used radio doppler as one way of measuring the changing position of airborne objects, and they were a feature of all the Woomera missile ranges until the early 1970s. A very simple version was the 'black market' single station reflection doppler mentioned in Chapter 11, set up by David Robertson at Port Wakefield for LRWE's very first rocket firing in February 1949. A transmitter behind the launcher radiated a simple continuous wave (CW) signal, and a nearby receiver picked up echoes reflected by the receding missile, which were slightly lower in frequency because of the doppler effect. This received signal was mixed with one direct from the transmitter, giving a beat note in the audio band with a characteristic rising pitch as the missile accelerated. It was captured on a wire recorder and photographed by a camera mounted in front of an oscillograph. By recording it along with a timing signal, the recession velocity of the missile relative to the ground station could later be measured.[6] Robertson had to place his antennas carefully so as to minimise swamping of the receiver by the powerful transmitter, and during the trials he developed a simple 'anti-signal unit' to reduce this further: in effect it fed an almost equal and opposite cancelling signal into the receiver.


Dr David Robertson (1969 photo).

This simple single station reflection doppler could only give one component of velocity, along the line of sight to the missile. In order to measure all three components in three-dimensional space, Robertson set up a three station system at the interim Range F, with transmitter and receiver pairs on each flank of the range as well as behind the launcher.[7] It was used for the second series of 4 inch LPAA trials in late 1949, with the optimistic claim that its data could be used to compute trajectories up to 2.4 kilometre range, to an accuracy of 1.5 metres and 5 metres per second in time. Now doppler measures changes in position, not absolute position, but by using a camera to record a 'fix in space' during flight, the complete trajectory was derived.[8] The reflection doppler was transferred to Range G for the next series of 4 inch LPAA trials in August 1950, but with the addition of a transmitter and two receivers to give a five station system, so as to allow several independent computations as a check on accuracy. Although like the early 'black market' doppler it was only intended as an experiment, it was soon pressed into service for other missile trials on this range. Parts for a proper working system were already being developed and manufactured by the

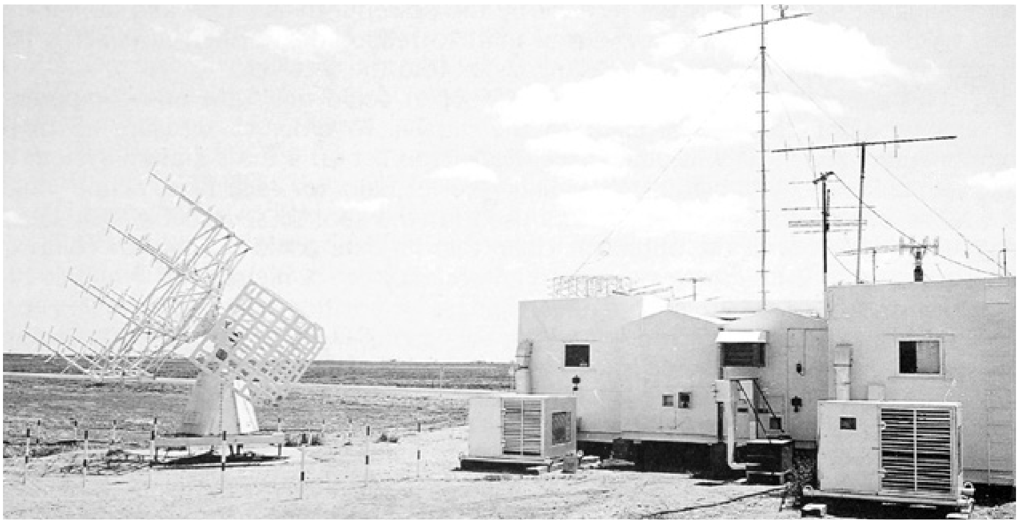
Australian electronics industry, including transmitters by Philips and receivers by EMI.

Reflection doppler only worked over short distances as the echoes received from the small missiles of the day were weak, but the results could be dramatically improved by fitting a transponder in the missile. This also solved the problem that reflection doppler gave unwanted echoes from anything that moved, such as jettisoned boosts or even traffic on nearby roads, and these could confound or even obliterate the wanted signal. Since the transponder retransmitted at a different frequency, to which the receivers were tuned, other echoes were effectively ignored. Even before the Port Wakefield trials the Radar Research and Development Establishment (RRDE) at Malvern in Britain had already developed a transponder system. Known as the Velocity Measuring Set (VMS), it was intended for RTV1 trials in both countries. A 104 megahertz CW signal of one kilowatt power was beamed along the missile's flight path. Spike aerials in the RTV1 nose picked up the signal and fed it to the transponder where it was amplified, frequency doubled, again amplified and finally retransmitted at 208 megahertz to a number of ground receivers, initially one back at the transmitter and one on each flank. At each receiver station the 208 megahertz signal, now shifted slightly in frequency because of the doppler effect, was mixed with a 208 megahertz reference signal with no such shift. The difference or beat note was photographed off a video display at each of the three receiver stations, and from these records the three components of missile movement and velocity could be computed.

The VMS equipment was installed on Range G in late 1950 and a number of Doppler Test Vehicle (DTV) rockets were fired to check it. RRDE had developed these DTVs by fitting the old war surplus 3 inch UP anti-aircraft rockets with flare heads, into which RTV1 type transponders were fitted in place of the flare material.[9] After the inevitable teething troubles had been overcome, the VMS equipment was used for RTV1 trials on Range G. But it had one obvious drawback: a transponder was essential and not all missiles were large enough to take one. So the experimental reflection doppler stayed at Range G until it closed in 1954. When missile trials began to shift progressively from Range G to Range E in 1953, a multi-station reflection doppler system was installed there, using the Philips transmitters and EMI receivers already on hand, together with some British equipment. When the RTV1 trials were transferred to Range E early in 1953, the VMS equipment went there too, with some upgrading. By the end of the year both systems were working satisfactorily and were handed over to Range E staff to operate and maintain.

In 1953 transponder doppler was only used for RTV1 and DTV trials, but over the next seven years many missiles were fitted with smaller and lighter transponders. By 1960 all missiles fired at Range E had them; even the small sounding rockets, which was just as well since by then the rockets were reaching further or higher than the reflection doppler could happily cover. So in 1961 this outmoded equipment was removed.

By this time the Range E transponder doppler had grown greatly since the Range G days. As well as the rear transmitter and receiver, there were now six receivers at four sites, two on the left flank and two on the right, which gave satisfactory cover out to 180 kilometres. In place of the film recorders used at Range G, the output beat signals from each flank receiver went by land-line to the rear station where all were recorded on a multi-track



The rear station of the Range E transponder doppler system.

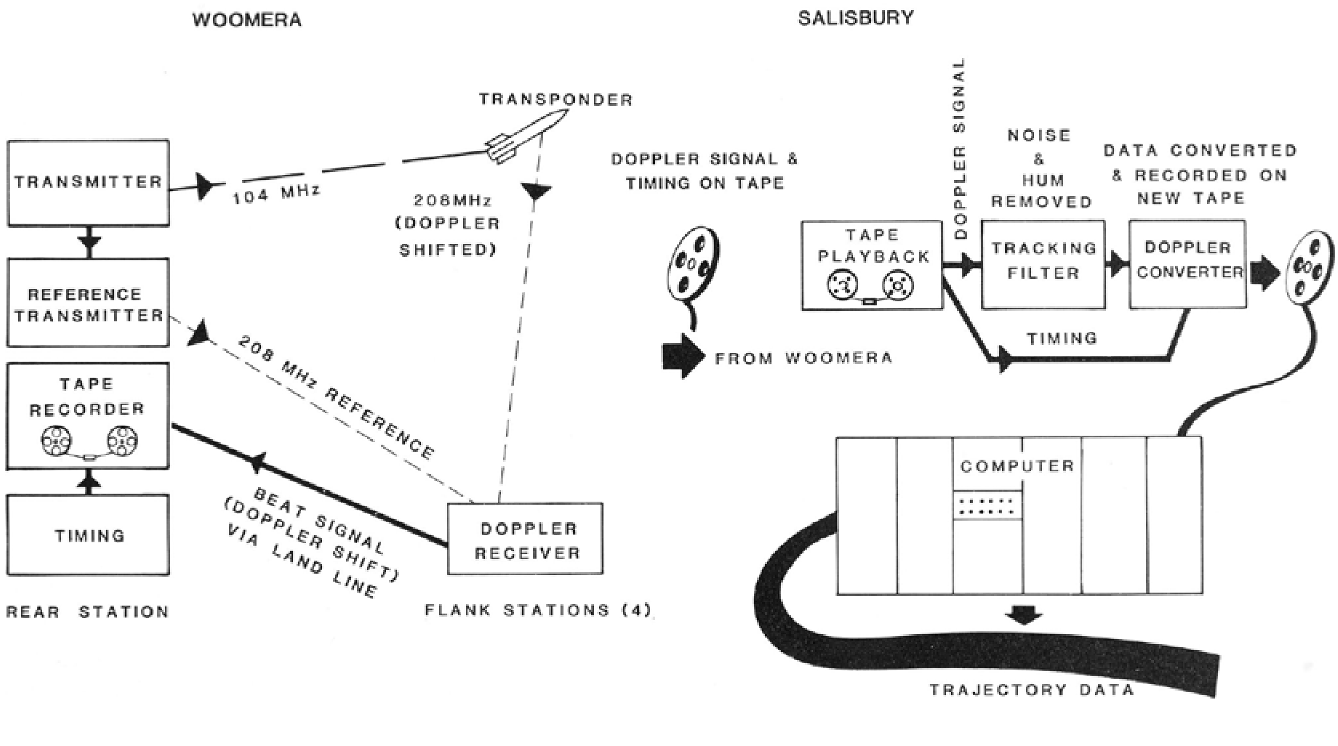
tape recorder along with a 5 kilohertz timing signal. The tape was afterwards processed automatically at Salisbury by the Maths Services Group. Here each track was replayed and fed to a doppler converter, which transformed the analog data information to a digital format compatible with the IBM 7090 computer used for data-processing, which it did by repeatedly measuring digitally the time interval for a fixed number of doppler cycles. These readings were recorded on another tape, subsequently replayed into the IBM 7090, which effortlessly computed the missile position, velocity and acceleration. To ensure that the converter did not count spurious noise spikes, the tape output was fed through a narrow band filter which cleverly tuned itself to the varying doppler frequency. While the initial work on the transponder doppler had been done by RRDE, WRE took over an increasing share from the mid-1950s onwards. It was led by D. J. (Doug) Mudgway in Electronics Techniques Group until he went to work for the Jet Propulsion Laboratory in California in 1961; then A. A. (Alan) Smith took over until the reorganisation of 1968.

Doug Mudgway

Doppler never supplied information in real time, but during the early 1960s it looked like becoming the supreme trajectory recording system, capable of fixing position as well as velocity throughout the whole flight of second generation guided weapons like Bloodhound Mk 2. The prospect was an attractive one, for doppler could manage with five sites and a staff of two or three, compared with ten sites and thirty operators for the Contraves system. What is more, doppler data were reducible automatically, unlike the kinetheodolite films which had to be put through the Boscar readers manually. Yet despite these obvious advantages doppler never really challenged the Contraves even in determining velocity. In fact it went into a decline in the 1960s. Part of the reason was that many of the missiles under test, like Rapier and Seawolf, were too small to carry transponders. More important were doubts about doppler's accuracy.

In an attempt to resolve these doubts, a series of high altitude night trials were held in which an aircraft fitted with transponders and a flashing light flew between two Wild ballistic camera sites. Trajectories computed from doppler, FPS-16 radar and Contraves were compared with those from the highly accurate Wilds. Doppler did not do too badly in these tests, but odd discrepancies still existed in some trials, particularly those employing freely spinning missiles. These errors were not fully diagnosed until 1974 and then it was found impracticable to correct them.[10] Already the data reduction people had lost confidence in doppler except for a few non-spinning missiles. By the early 1970s the transponder doppler system in Range E lay moribund and it was stripped out completely with the run-down. Doppler never achieved its early promise, and in retrospect we see how very shrewd the instrumentation planners were in not putting all their eggs in one basket by neglecting the rival techniques.

The transponder doppler recording and converter system in the early 1960s.



THE MTS AND X-TRACKERS

The 6 centimetre Missile Tracking System (MTS) was an electronic tracking network used on Range E from 1954 to about 1968. Like the kinetheodolites it measured only angles, from which trajectory was triangulated; but unlike them it could do so in real time. The function of the MTS changed radically during its lifetime, and in the end part of it underwent a metamorphosis when it was used for an associated optical tracking network, which survived almost to the end of the project.

The MTS was also developed by RRDE in England. In 1948 the British were considering what trajectory measuring instruments might be used at Woomera, and had concluded that neither the Askania kinetheodolites nor the No. 3 Mk 7 radars (doppler was presumed to be good only for measuring velocities) had the ability to track weapons flying over the very long distances which it was then presumed the Range would be used for. The radar range could be extended with transponders, but again they would fit into only the largest missiles. Further, it was no simple matter for more than one radar to share the same transponder, as would be necessary for the relay system envisaged at the time for the string of radar equipped observation posts ultimately stretching from Woomera to the Indian Ocean. So a group was set up at RRDE to come up with an answer. What emerged was a proposal for a network of radio trackers that would automatically lock on to a beacon in the missile. The latter's position could then be fixed by triangulating azimuth and elevation angles from a pair of stations.

M. S. ('Kirk') Kirkpatrick.

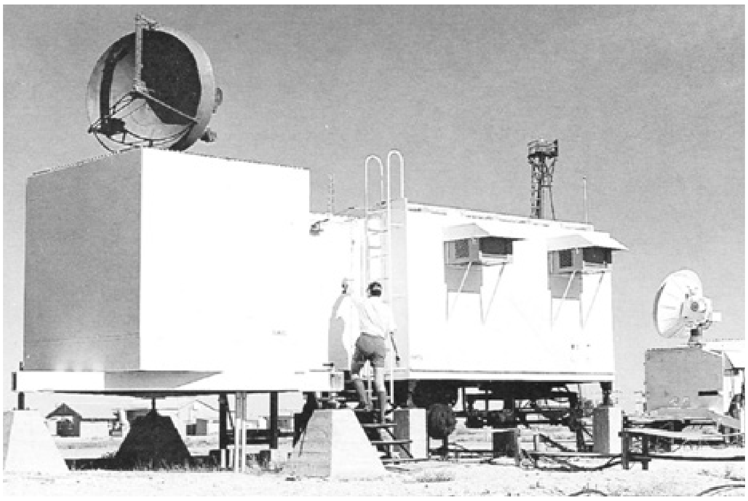
RRDE went ahead quickly with development work, saving time by using the dish reflectors and power-driven mounts from the No. 3 Mk 7. The radio beacons were simple, reliable, one-valve transmitters generating a CW signal on the C-band (6 centimetre wavelength). They were small, light, economical on power and, unlike the multi-valved transponders, would fit into most of the missiles fired at Woomera. Suitable receivers for the ground stations were developed by a young Australian trainee, M. S. Kirkpatrick, during a two-year spell as a trainee at RRDE. Many years later 'Kirk' took charge of the joint project component of WRE, of which he was Director for a short time before his retirement.

As the MTS dishes automatically tracked the beacon the elevation and azimuth angles were read out in two ways. At each station the scales were photographed in the light of a strobe lamp flashing four times a second, the film being developed and read back at Salisbury, in much the same way as for Askania kinetheodolites. In the system eventually installed at Range E coded data were transmitted by land-line from each station to a central point, where the angular data from two selected stations were processed in real time by an analog computer which worked out by triangulation the Cartesian co-ordinates of the missile.

Selected co-ordinates were then displayed on two-dimensional plotting tables to give plan position (X,Y) and height-distance (Y,Z) displays as needed. Thus the MTS was useful both for recording trajectory and for real-time displays during trials. The accuracy of the system lay midway between that of the No. 3 Mk 7 radar and the kinetheodolites, but it had the advantage of a much better range than either: up to 150 kilometres for two stations. Any number of additional stations further out could be added, and the beacon used by them all.

By early 1951 RRDE had completed the development, tested the experimental

MTS station PI (*left*). The dish used was the same as that on the No. 3 Mk 7 radar alongside. At right is the operating position inside the van.

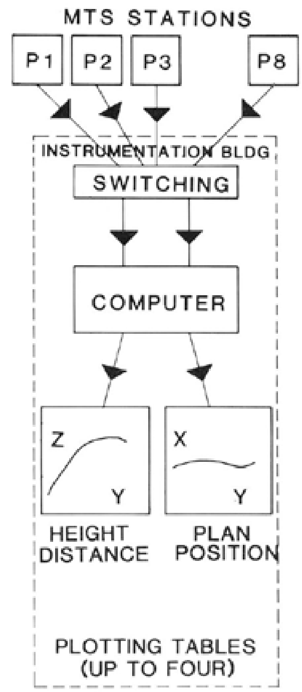


equipment at Aberporth and arranged a contract with the British firm J. Langham Thompson to manufacture equipment for the first two MTS receivers. Meanwhile Salisbury was making a great effort to design and fabricate special aerial cubicles, needed for accurate stable levelling and setting up, and vans for the receivers. It all came together in August 1953 after delivery of the British units, and by early in the following year the first two stations had been installed on Range E and tested by flying a Mustang aircraft fitted with the 6 centimetre beacon. One station (PI) was behind the rangehead and the other (P2) some 25 kilometres out on the right flank, on the road to Parakylia homestead.

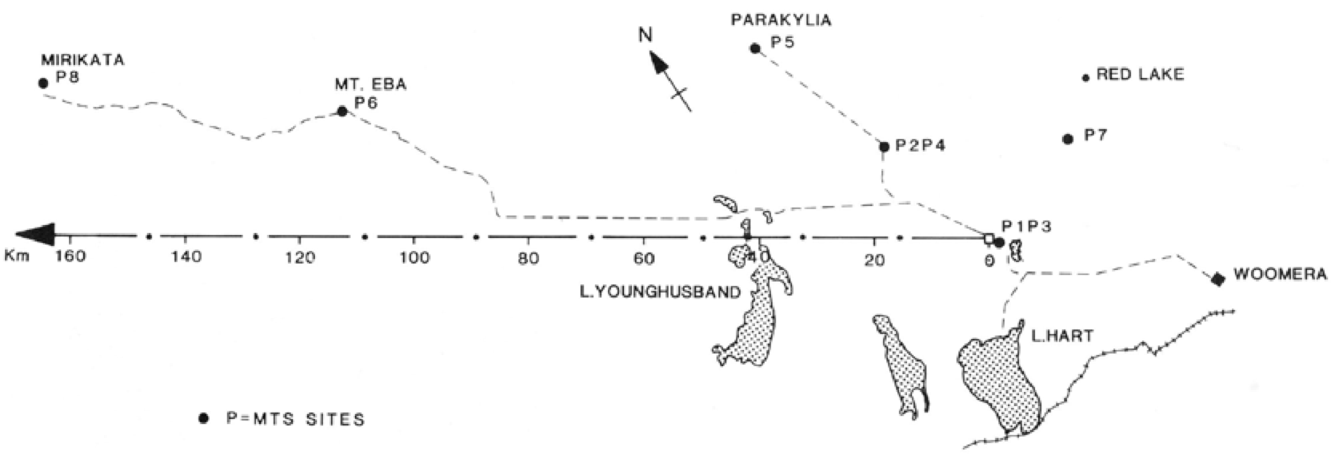
By now the MTS had lost its expected function. The long range missile had been shelved for the time being and the accent was on short range anti-aircraft guided weapons like Seaslug and Red Shoes, trials of which were imminent. The Contraves were soon to be installed and the doppler system was being improved; both were more accurate than the MTS and had plenty of range for the forthcoming trials. As a data recorder the MTS was only a back-up, but not so its real-time readout; that came into its own after 1954 for navigating the pilotless target aircraft, because the No. 3 Mk 7s used earlier lacked both the range and accuracy to cope with some of the planned interception trials. Beacons were fitted in the target aircraft as well as in the attacking Sabre aircraft used in the early air-to-air trials. But the two MTS stations could track only one airborne object at a time. To overcome this deficiency the stations were duplicated in 1955, with PI and P3 at the rangehead and P2, P4 on the right flank: RRDE supplied the basic equipment as before. Thus the MTS could be used for navigation of the manned aircraft that fired air-to-air guided weapons such as Blue Sky, and of its target aircraft at the same time. For trials of ground launched weapons such as Thunderbird, one pair of MTS stations could give real-time safety surveillance of the missile flight while the other was used to navigate its target. The MTS later replaced the No. 3 Mk 7 radars as the source of acquisition data for Contraves kinetheodolites.

This completed what was known as the 'short range MTS', but five more sets were already being manufactured in Britain for an extended network capable of tracking out to 300 kilometres.[11] During the next three years three new MTS stations were set up in turn using the new sets: P5 at Parakylia, P7 near Red Lake and P6 not far from the Mt Eba homestead. The last station P8 was set up in 1960 at Mirikata for Blue Streak. However, the MTS soon began to contract and the last to come was first to go. In 1962 the set at P8 was removed, for by this time an FPS-16 radar had been working long enough at Mirikata to prove that it could provide all the real-time tracking needed for long range trials, and more accurately than MTS. A study began that same year on replacing both the MTS and the No. 3 Mk 7 radars, both recognised as obsolete, and this culminated in the installation of two new Adour radars in 1968. The old MTS was now redundant and was removed after the Adours had been proven.

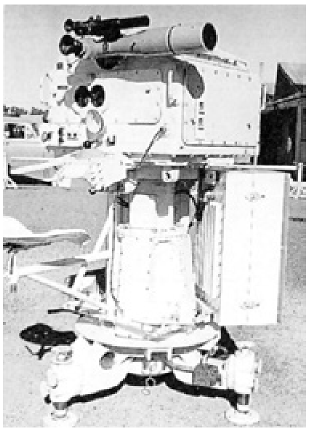
Associated with the MTS was another known as the MTS Optical Tracking System or Optical MTS; or more usually after their Range code letters as the X- trackers. X-trackers were developed at WRE in the late 1950s primarily for safety tracking in real-time at low altitudes where electronic instruments were unreliable, and they were placed at each of the six MTS single and dual sites. They were a combined optical and electronic instrument operated by one person sitting on a large steerable mounting. Using a joystick to steer the mounting,



The MTS real time display system at Range E, mainly used to navigate target aircraft during interception trials.



The MTS network at its greatest extent in the early 1960s was useful out to 300 kilometres. MTS then began to contract as the FPS-16 radars were installed at this time.

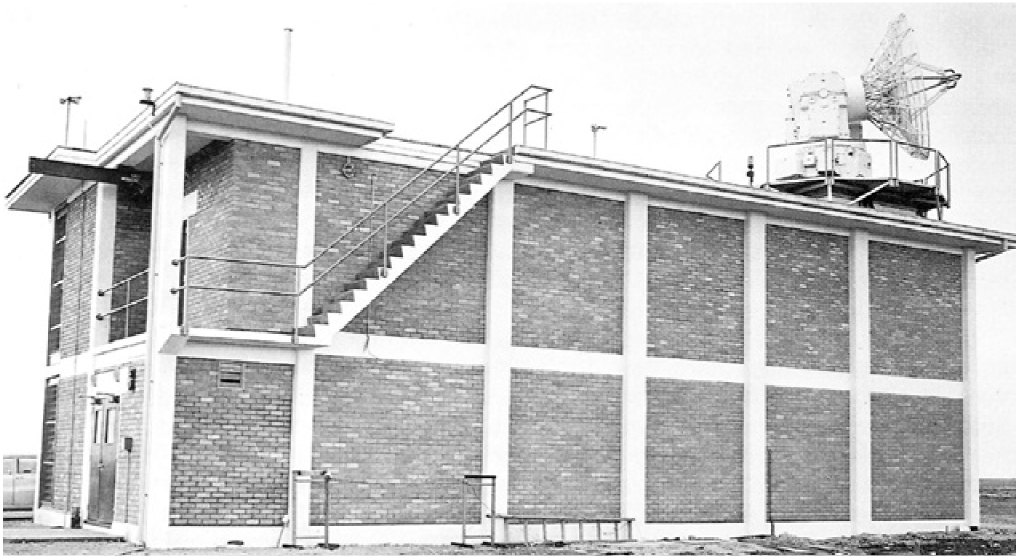


An optical tracker, usually known as an X-tracker.

the operator sighted through an elbow telescope and kept a pair of cross-wires aligned on the target. The bearing and elevation were then transmitted direct to the rangehead via the MTS data link. There was also an acquisition data link to the adjacent MTS set, so that either could help the other to find the target.

Development of the X-trackers began in 1956, mainly by Jack Poole of El Group with help from Optical Group. He modified some existing AA No. 1 Mk1 optical trackers, which were British Army units used for anti-aircraft gun laying in association with the No. 3 Mk 7 radars. Five of the six trackers were installed in time for the first Black Knight launch in September 1958. At the rangehead the angular data from four of them were computed and fed to plotting tables. These displayed not only present position of the missile during early stages of flight but its computer predicted impact point should its engines happen to cut off at that instant. The sixth tracker went in at P8 Mirikata after the MTS station had been installed there in 1960.

The X-trackers survived the replacement of the MTS by the two Adour radars. They were still needed for safety tracking of the big high altitude rockets such as Black Knight's successor Sparta, Europa 1 and Black Arrow, and also as one of the sources of acquisition data. As they were only needed during early flight, until the FPS-16 radars were acquired, the outlying stations at Parakylia, Mt Eba and Mirikata were closed down and the trackers used to duplicate the stations closer to the rangehead. They were all sold off at the end of the project.

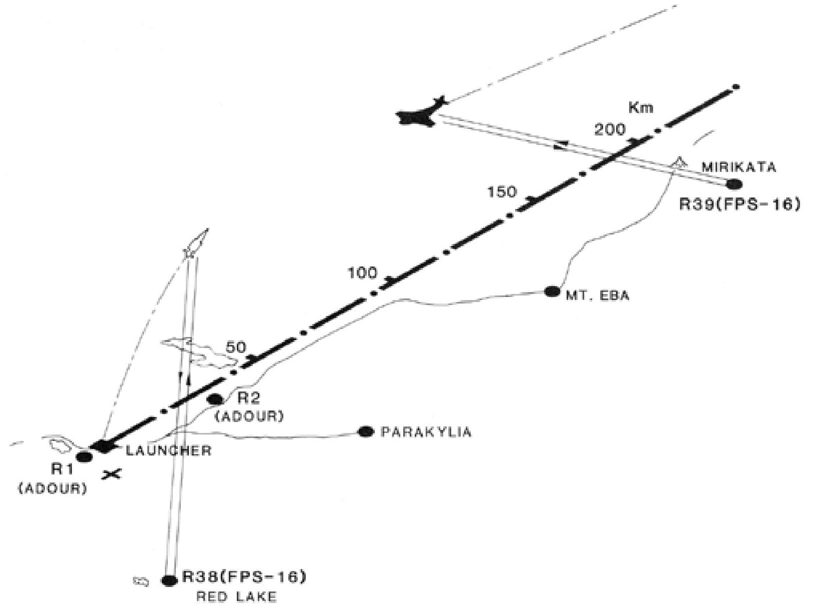


An FPS-16 radar building.

THE PRECISION RADARS: FPS-16 AND ADOUR

Late in 1959 two of the very latest American precision radars arrived at Woomera and were installed in special buildings. They were C-band (6 centimetre wavelength) FPS-16 radars. They had little in common with the wartime British No.3 Mk 7s which they replaced, except that both were tracking pulse type radars. Otherwise they were vastly more powerful and sensitive, particularly when the target was fitted with a small Cband transponder. And they were much more precise and versatile, producing a digital output well suited to automatic data processing and recording. For all these reasons the FPS-16 radars were useful for trajectory recording and for critical safety tracking. They were by far the biggest instrument ever installed on the Woomera Range: each one filled most of a two-storey building with the tracking dish on top.

Like much of the upgrading of Woomera instrumentation that began in the late 1950s, the new radars arrived for Blue Streak. In August 1957 a combined RAE-De Havilland mission arrived at WRE to discuss the big project, when it became apparent that very exact tracking of the missile would be essential so that its engines could be shut if the missile threatened to transgress its flight corridor. The MTS was just not precise enough for this job. Soon afterwards WRE's two top instrumentation experts, Boswell and Kirkpatrick, discovered during an American visit that ranges such as White Sands and the Atlantic Missile Range



Location of the RCA FPS-16 precision radars, and the later CFTH Adour sets at R1 and R2.

were relying heavily on the recently developed FPS-16 radars, both for safety tracking and for down-range trajectory measurement in their ballistic missile trials. And so two were acquired for Woomera, one to go at the rear of the Blue Streak launcher and one about 170 kilometres down-range. These extremely intricate devices were not cheap—to the journalists of the day they were the 'million pound radars'—yet they cost the joint project nothing apart from the not inconsiderable price of spares, documentation, building and installation work. America presented them as a gift, part of the Mutual Weapons Development Project, a defence aid agreement.[12]

The rear FPS-16 site (R38) was at Red Lake, just north of the long-abandoned Range A. The down-range site (R39) was 170 kilometres from the Blue Streak launcher, past Mt Eba. Here was also installed other Blue Streak instrumentation, including ballistic cameras and telemetry receivers, together with living quarters, and the complex was called Mirikata, another Aboriginal word meaning 'morning star'.

Mirikata and Red Lake both survived the Blue Streak cancellation because the FPS-16s were fully employed on other long range trials such as Blue Steel, Black Knight and the European satellite launcher which was then on the horizon. Studies were already in progress on the likely coverage and accuracy of the FPS-16 radars for tracking Bloodhound Mk 2 and other forthcoming long range guided weapons as well, and their targets. And the Americans had been promised some return for their generosity. The radars could be used for certain satellite tracking missions until the NASA Deep Space station at Island Lagoon was brought into operation.

By 1960 the staff of Ranges Group had finished their acceptance tests and taken them over from the RCA installation team. Extensive performance tests of the two radars continued for a few years, but in the meantime they were drawn more and more into trials. The earliest application to a weapon trial was Blue Steel: on 30 November 1960 R38 was used on the first of the full scale missile trials, a drop of an unmotored vehicle from a Valiant aircraft. The following year Red Lake took part in the first US manned space flight program, Mercury, when NASA installed a radio communications and telemetry receiving station alongside the radar building. And thus it was that Red Lake became a component of the global tracking network used in the historic space orbit by John Glenn on 21 February 1962.

During the decade following, both FPS-16 radars formed part of the safety tracking systems for all the space vehicles launched from Woomera: Europa 1, WRESAT and Black Arrow. For the Dazzle re-entry physics program of the later Black Knights, they enabled the special optical and radar instrumentation to acquire the elusive head as it entered the atmosphere. But their bread and butter application was to trials of the long range guided weapons, not only Blue Steel but Bloodhound Mk 2, VR725 and Sea Dart as well. They were little used for short range and low altitude trials as they were too far from the rangehead for these, and with their narrow beams they needed time and good acquisition data to find and lock on to their targets.

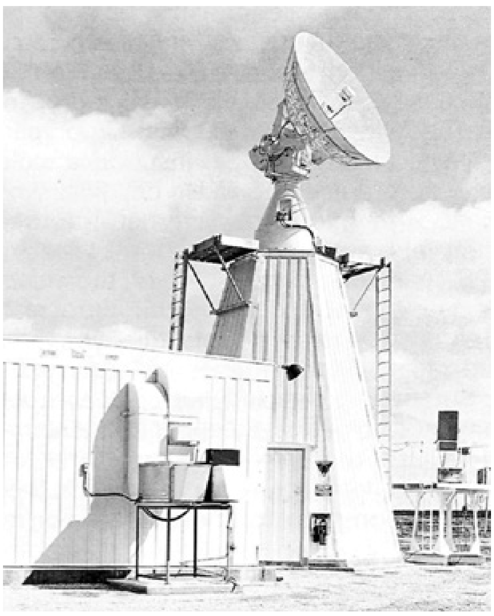
The two FPS-16s were not operated by Army servicemen like the No. 3 Mk 7s but by civilians, initially of Ranges Group. Because technical staff were in short supply during the boom period of the early 1960s, private firms under contract operated and maintained the radars: first Amalgamated Wireless Australasia between 1962 and 1975, and then Fairey.[13]

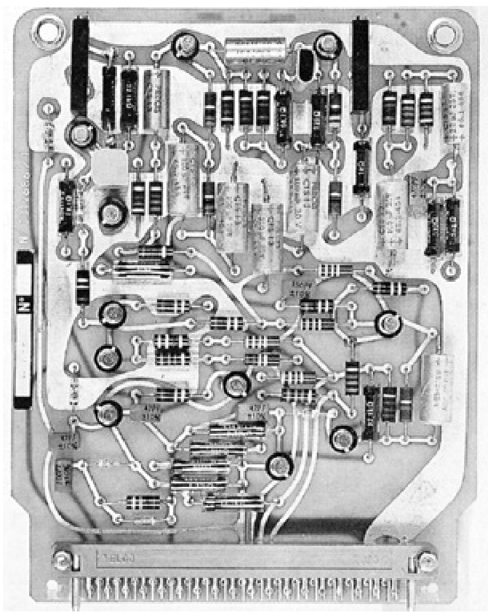
The FPS-16s became superfluous during the run-down because they were expensive to maintain and operate and had no function in the small post-project work of the Range. However, they avoided the ignominy of being sold off for scrap. The one at Red Lake was sold for $30 000 to the US Air Force. This might look like sharp practice considering it had been a gift, but the project had paid the US very much more than that amount over the years for documentation, upgrading and spares. The buildings were eventually sold off to the Roxby Downs station on whose land they stood. The Mirikata radar went to the Radar Division at Salisbury for experimental work and Mirikata itself became a motel. Thus ended a period of nearly twenty years in which the two FPS-16 radars had clearly held top status among the many instrumentation systems at Woomera.

The disposal of the FPS-16 radars in 1979 was probably inevitable. There were two other precision radars on the Range which could cope with navigation, safety tracking and acquisition for the very modest short range trials that were envisaged for the future. These other radars were the two French CFTH Adour sets at posts R1 and R2, and they had been there since 1968.

Early in 1962, soon after the FPS-16 radars were commissioned, a study had begun on what to do with the obsolete No. 3 Mk 7s and the MTS. Not only were they becoming more difficult to maintain but performance was deteriorating. Then they needed a total staff of thirteen to operate and maintain them, and staff was in short supply. Yet they had to go on being used in day to day trials at relatively short ranges and altitudes, for target navigation, for safety tracking and to provide acquisition aids. The FPS-16 sites, established for long range trials, were just too far away. A submission of March 1965 recommended that new radars be obtained to replace the three No. 3 Mk 7 radars, six MTS sets and another interim surplus British radar, Yellow River, on loan to the Range.[14] As a result, a joint UK-Australian team of radar experts visited Paris, Rome and an Italian range in Sardinia, and narrowed the choice down to two radars: the French Adour or the Italian Selenia. Tenders were invited and the one from the French Compagnie Française Thompson-Houston (CFTH) finally accepted for two Adour radars, at a cost of about £1.3 million. By June 1968 the two radars had been delivered, installed in their prepared sites, the data links connected and the whole system commissioned.

The Adour radar was sometimes regarded as a poor man's FPS-16, and certainly it lacked the latter's very high performance. Still, it could track a typical missile without a transponder up to 150 kilometres or so, which was adequate for its Woomera role, while its accuracy was more than sufficient for navigation, safety tracking and acquisition purposes. And the Adour had the edge over the FPS-16 operationally. It used transistors on plug-in





Right: Adour radar post R1.

Far right: A plug-in circuit board used in the Adour radar.

printed circuit boards rather than valves, which made it more reliable and easier to service, and it did not require a long warm-up time. A team of six was enough to operate and maintain the two Adours, against eleven or so for the two FPS-16s.

The two sites (R1 behind the main launcher area and R2 on the right flank, close to the Contraves site K15-K16) were well placed to cover guided weapons trials, which were the main tasks for the remainder of the joint project. They complemented perfectly the FPS-16s which were used for the longer range and high altitude trials. Between them these two pairs of precision radars were for the next decade the standard instrumentation systems for safety tracking, for navigation, for acquisition services and as a backstop to Contraves on trajectory recording. One or other system was called up on nearly all trials, sometimes both.

The two Adours lasted longest. Long after every other item of the electronic tracking system had vanished from Woomera with the close of the project, the veteran Adours were still in place for the occasional Australian trial.

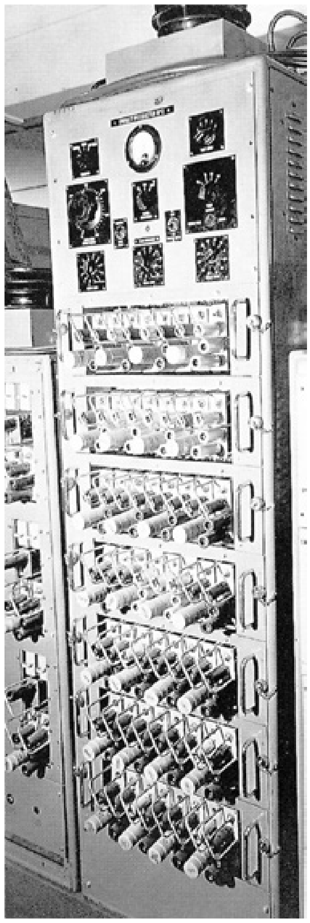
THE TRACKING DATA CENTRE

Most of the electronic and optical tracking systems mentioned so far formed a network covering all of Range E, along which information flowed to or from the rangehead. The nerve centre was a room in the Instrumentation Building where the information was displayed for safety and navigational purposes and whence acquisition data flowed out to the instruments down-range to help them find their quarry. Known at first as the Plotting Room and later as the Tracking Data Centre (TDC), it grew to several times its original size to accommodate the continual expansion of its complex computing and display equipment. More than any other Range facility, the TDC was constantly being changed from its establishment in 1955 until the end of the project and afterwards.

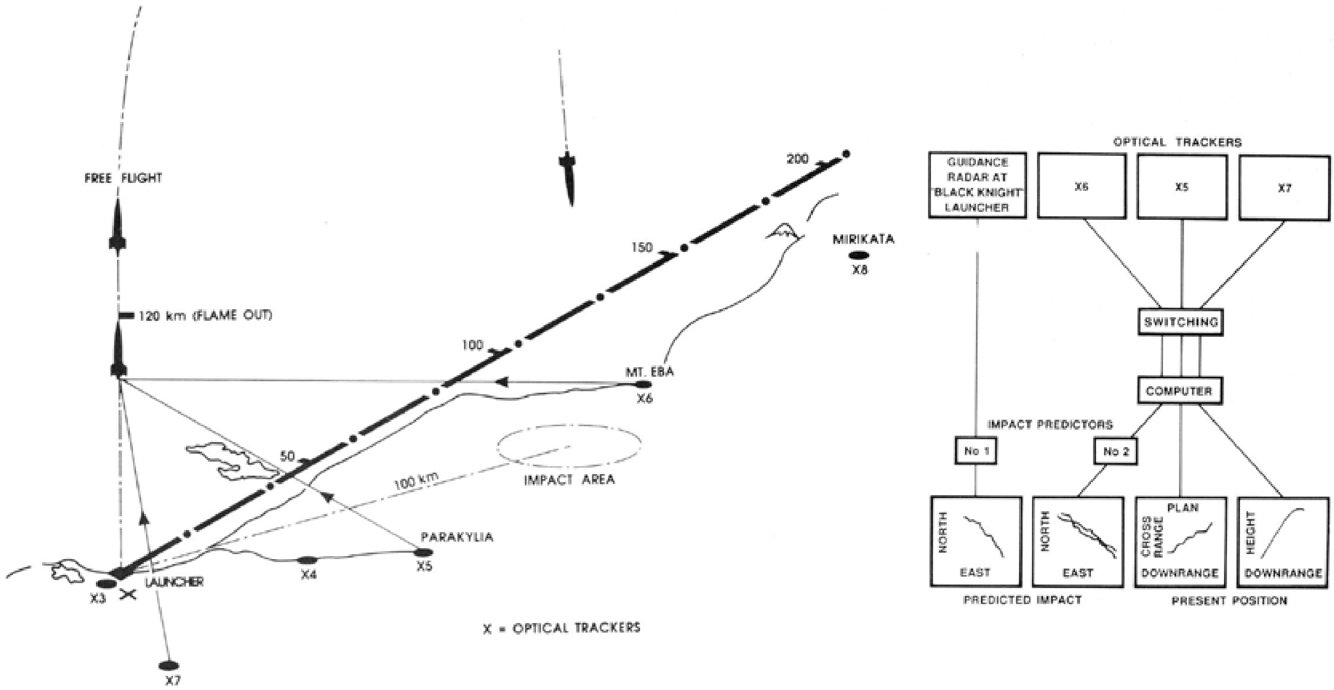
As we have described in Chapter 10, between 1949 and 1957 the output data from the No. 3 Mk 7 radars at Range A were displayed on plotting tables in an adjacent small building, in order to navigate the bomber aircraft from the ground so that their bombs could be dropped at the right height, speed, direction and release point. At Range E the system developed along different lines. Here the merits of the MTS as a navigation aid for the ground control of aircraft became apparent soon after its installation in 1954. Because plans for long range missile tracking had been deferred, the later MTS receiver stations were placed in the best position for tracking not only medium range missiles but manned and unmanned trials aircraft as well.

At this time analog computers were used in the Plotting Room to convert the digital data from the MTS stations into voltages that accurately represented the position of the airborne beacon. These voltages drove EMI plotting tables, which were horizontal surfaces about a metre square with an ink pen mounted on a gantry to plot automatically in two dimensions. One such table usually traced out the course of the missile or aircraft on a map, while the other plotted its distance down- range and its height. Together they showed what was happening at that moment, so the aircraft could be navigated and the flight path of missiles monitored for safety purposes. In addition, the table plots were useful as instantly available records, giving the experimenter a good idea of what his missile had done immediately after the trial. They were also helpful to the recovery team. The value of being able to see precisely what was happening in the sky above the Range was obvious, and the system was soon enlarged to accept data from the nearby No. 3 Mk 7 radars as well as the MTS. By 1959 there were four separate EMI plotting tables and their related analog computers, each of which could be manually switched to select tracking data from any pair of MTS stations, any of the six optical trackers that shared their data links, or any of three No. 3 Mk 7 radars. Thus the position of almost all airborne vehicles on the Range could be monitored thoroughly.[15]

The arrival of the Black Knight rocket in 1958 created the next big expansion in the electronic tracking network. Black Knight was fired almost vertically, reaching a height of up to 800 kilometres before plunging back to earth, and if its guidance system went awry it could certainly land well outside the Range. Two impact predictors—designed, built and installed by WRE—were brought into use by 1959 to monitor the flight of Black Knight. They worked on different principles: No.1 made use of signals from the ground guidance system, while No.2 used data from the MTS optical trackers. Both impact predictors took the



The No. 2 analog impact predictor, which used thermionic vacuum tubes

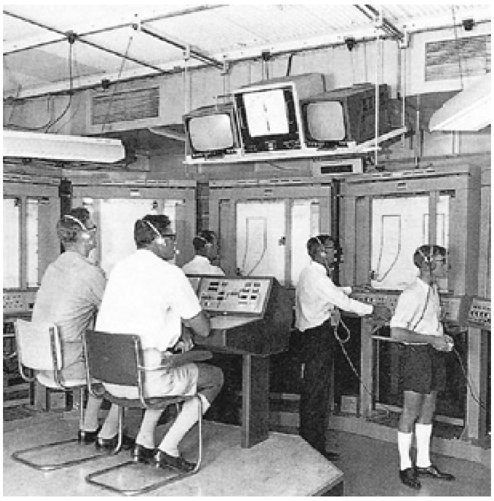


The 1959 flight safety tracking system for the Black Knight re-entry rocket.

measured position of Black Knight at each moment of flight and calculated where the rocket would land if its engine were to cease thrusting at that very instant. Safety policy dictated that this predicted impact point should be monitored throughout and the rocket destroyed if there was any risk of impact outside the zone defined for the trial. The Flight Safety Officer had manual control of the self-destruct system for much of the flight, and since he had to decide and act quickly under pressure he needed a simple and unequivocal display. Thus the predicted impact point was plotted automatically on a map of the Range, on which had been marked out not only the lines defining the impact zone but also the cut-down lines well clear of them. The FSO had authority to press the destruct button the instant that the moving plot of predicted impact—the 'walking impact point'—transgressed the cut-down lines.[16] As it was linked to Black Knight's guidance system, Impact Predictor No.1 disappeared with the end of that project in 1965. The other predictor, modified to increase its range, continued to be used for flight safety throughout the following program of high altitude rocket trials, including the ELDO, WRESAT and Black Arrow satellite launcher trials.

Far wider in scope were the improvements resulting from a British mission in 1957 to discuss the forthcoming trials of the intermediate range ballistic missile, Blue Streak. There followed a review of the four elements of the elaborate Range flight safety system that would be needed. They were: a means of accurately tracking the missile; of predicting its impact point; of displaying this point and of cutting fuel to its engines. We have already seen how the two FPS-16 radars were acquired for Blue Streak tracking. For displaying both the present position of the missile and its walking impact point, six new plotting tables were acquired from the US. They were more accurate than the EMI tables and their display was vertical, so that all six arranged in an arc could be watched by the Flight Safety Officer in the Plotting Room. The fourth element was the WRE Break Up System (WREBUS): a radio link from ground transmitters to receivers in the Blue Streak missile which on command would shut down the engines and trigger an explosion to disperse the propellants. The remaining parts of this flight safety system were what would today be called the 'information technology' components. The digital data outputs of the FPS-16 radars at Red Lake and Mirikata had to be converted to a format suitable for line transmission to the Plotting Room, where receivers would sort out the multiplexed data. Then the data had to be processed in a computer which would solve the ballistic equation at each instant and display the result.

The system that was eventually devised to meet these requirements constituted the single most complex electronic system ever designed in Australia up to that time, and it was largely in the hands of three young scientists: Ian Hinckfuss, Ian Macaulay and Ron Keith. All were members of Information Studies Group under Fred Thonemann, but earlier Hinckfuss had been a trainee for two years or so at RRDE and Malvern and Macaulay for a similar period at nearby TRE. In particular Hinckfuss designed and built what is believed to have been the first digital data transmission system in Australia.[17] It worked extremely well from the outset, and predated by many years similar Telecom facilities.



Far left: The vertical plotting tables, and the Flight Safety Officer console on its raised platform.

Left: DIP, the most demanding and controversial Range instrumentation ever developed by WRE.

By far the most expensive and technically advanced part of the main system, however, was the digital computer at its heart. Thonemann, who had lost out on the chance to build such a computer, LEDAC, from scratch at Salisbury a number of years before, made out a case that no computer on the market in 1958 could meet the demanding specifications. This time he succeeded: approval came for two machines to be built by WRE. Thus was born the Digital Impact Predictor (DIP). DIP was the most complicated and demanding piece of Range instrumentation ever developed by WRE, and the most controversial. Not only did it have to solve the complex ballistic equations ten times a second and make the results available instantly even while the rocket was speeding along its trajectory; it also had to trigger the destruction of the rocket under certain conditions without consulting the operators. Finally, it provided acquisition data to other local tracking instruments (and in teletype format to the instrumented impact zone far away at Talgarno). This was well before the time of integrated circuitry, and DIP was made of individual wired-in components including 13 000 germanium transistors and 8000 diodes. A strong team was assembled to tackle its design and construction. Apart from Hinckfuss, Macaulay and Keith there was Trevor Robinson and two British scientists under contract, Bill Rundle and Dave Rogers. In addition, Ken Todd was asked to design two small analog impact predictors, which would use data from the X-trackers during the very early stages of flight, before the FPS-16s could be expected to lock on and track. Peter Goddard and others in Mathematical Services began work on programming DIP.

But in these early days the linchpin of the DIP design was undoubtedly the Hinckfuss-Macaulay-Keith trio. Emlyn Jones, the Superintendent at the time, recalls one anecdote about Hinckfuss:

> He was a very nice bloke, an individualist with a marvellous brain. When he wanted to solve a particularly sticky problem he got a board out from somewhere and stretched out on it with his hands behind his head and his eyes closed. He would ponder the problem in a deep reverie and while he was doing it everyone knew they mustn't interfere with him because brain power was what the whole thing depended upon. On one occasion Boswell blew into his lab with a visitor. Boswell was just saying briskly, 'And this is where we're developing the Impact Predictor: work is going on very urgently with it,' when he stumbled across old Hinck flat on his board. I think at first Boswell tried to pretend he wasn't there. Eventually I nudged Hinck and got him out of his trance. He stood up.
>
> 'Ah, now Mr Hinckfuss,' said Boswell. 'Can you explain to Mr So-and-so what this thing will do?' Hinckfuss looked at the visitor dazedly, staggering a bit because he was deep in impact points and so forth. Everyone was waiting expectantly, but finally all that he came out with was, 'It counts, man!'
>
> I ushered them into the next room saying, 'Well, I think probably I should amplify Mr Hinckfuss's remarks.' Hinck went back to his board; I shut the door on him and delivered the presentation.[18]

Ian Hinckfuss: 'It counts, man!'

When Blue Streak was cancelled in April 1960 the FPS-16s and vertical plotting tables had been delivered and the first DIP was well advanced. Its completion was ordered and the second one cancelled. Before 1960 was out it became known that Blue Streak was to fly as the first stage of the Europa satellite launcher, so the pressure to complete its flight safety system was on again.

In June 1960 WRE's circuit design specialist George Barlow returned from a posting as Australian Defence Science Representative in Washington, and he was made head of the DIP team early in 1961. It was an awkward moment. Most of the components were finished, but the final assembly seemed to be taking forever. Much of the challenge had evaporated and the staff were starting to drift away; in Hinckfuss's case he was later to swap electronic engineering for an academic post in philosophy at the University of Queensland. Barlow's job was to pull it all together in time for the first Blue Streak firing in the ELDO program, scheduled for late 1963. Fortunately he had the right sort of diplomatic skills, which, given the past history of DIP, were sorely needed:

> I made peace with the engineers. As I understood the history, Engineering Wing had made one or two calls on Lab 1 in earlier Blue Streak days to see if they could be helpful and had been sent packing. We now had a number of severe problems concerned for example with overloading the frame in which the DIP was built, which simply cried out for engineering support. After a small meal of humble pie, I was able to persuade Gordon Brookman and his boys to help and they quietly and effectively took many of these difficulties off our hands. They were even tactful about the fact that DIP had grown several inches in height over its original design limit, and that a few courses of bricks had to be removed from the outside door of Lab 1 to get it out of the building.[19]

Early in 1963 began the arduous business of transferring the six metre length of DIP to the Instrumentation Building at Woomera. The engineers feared the effect of vibration on the hundreds of thousands of soldered joints, so DIP made the trip on a special truck with airbag suspension, crawling to Woomera at a snail's pace with the anxious Hinckfuss in attendance all the way. To everyone's surprise after a little recuperative work it was as good as ever.

By October 1963 DIP had proved itself during a special Black Knight trial (BK11) put on to test the flight safety systems. It was first used with Blue Streak during the first flight (FI) of the ELDO program in June 1964. Then it was the turn of Ranges Group to take over the machine promised to them more than three years earlier. After some teething troubles, DIP proved itself an invaluable and versatile computer. It predicted impact points not only for the later ELDO multi-stage trials but for the other space projects Sparta, WRESAT and Black Arrow, and it was used for special tasks such as predicting where the elusive nose cone of Black Knight would re-enter. But there is no doubt that in the early 1960s DIP was the subject of ferocious argument, revolving around its delayed gestation and the method of construction (all its component units were hard wired together rather than being connected with plugs and sockets). The following recollection is not atypical:

> The only major decision I know that Boswell ever made that was wrong was about the Impact Predictor for Blue Streak. George Barlow [had] cased the field. He'd been to the US ranges and he knew what they were doing and he knew the equipment that was available and as I understand it his advice was that we should put together an impact predictor based on commercially available equipment . . . The counter-argument being put to Boswell by the ineffable Freddie Thonemann was that we should build one here. I believe this argument waxed fairly long and fairly loud for a while and Freddie finally convinced him. We were bloody lucky that Blue Streak was cancelled when it was because otherwise we'd have been in the can completely. I chipped old Boswell about this once and he just put on that big bland smile.[20]

Emlyn Jones: 'Just get on with it. So we did. We built it.'

Emlyn Jones, who was the responsible Superintendent, has a contrary view:

> I chose to make the Predictor, rather than attempt to buy a general purpose computer and adapt it as a predictor, because it was very early days in computing. You couldn't buy an Impact Predictor as such. You couldn't even buy a computer off the shelf; it had to be made for you. And many of the designs being offered really existed only on paper. Their delivery dates and performance were not accurately known. They might cost half a million pounds. Getting through the purchasing procedure of such a thing in Australia posed a horrendous problem. Then you couldn't even work on the specification without first solving the prediction problem which in turn depended on the computer . . . which you wouldn't have except as a doubtful spec. As against that we had excellent design facilities and could make a device specifically for our particular safety problem, cutting out all that was irrelevant in the other option. We could buy the parts within current funding and start immediately. All we wanted was Boswell's OK. A lot of time went by before we got that decision. Then Boswell just rang me one day and said, 'You'd better start on it.' No formal approvals or anything—just get on with it, so we did. We built it.[21]

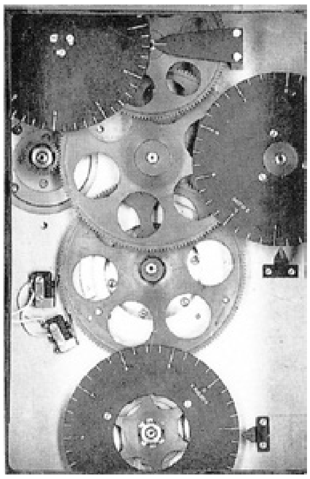
It is even more facile than usual to judge this decision from the standpoint of a later era, with its cornucopia of computer hardware and software. Both were barely beginning to emerge in 1958: Barlow recalls that at the time he first heard of DIP only one suitable American machine might have been available. Certainly, because DIP was years in the making, suitable hardware came on the market while it was still being developed; but this was hardly predictable at the beginning.[22]

In 1959, while the flight safety instrumentation team was busy developing DIP, another section led by John Rodger was hard at work on the problem of the acquisition system that was needed to aid narrow angle tracking instruments such as radars and Contraves to find their targets. Until then specialised analog computers had been used to process real-time tracking information from MTS or local No. 3 Mk 7 radars and convert it into a suitable form. In 1955 a local acquisition system had been installed to serve the cluster of radars, MTS sets and auto-tracking aerials close to the Instrumentation Building, and there was a similar local system at Mt Eba. The acquisition data sent out represented the local polar co-ordinates (azimuth, elevation, range). More recently another analog system, the Contraves computer, had been installed to serve the Contraves kinetheodolites at sites as far as K15-K16 some 30 kilometres away. But in 1959 the acquisition system needed extending, and the accent was changing from analog to digital data handling. The FPS-16 radars were to arrive shortly, and their digital output was to be transmitted to the rangehead by the Hinckfuss digital data transmission system. But data had to be transmitted back as well so that one FPS-16 could help the other acquire Blue Streak, and the forthcoming down-range Contraves would need acquisition data too. The decision had been made to develop a versatile digital acquisition system that could be used not just by local posts or by the limited Contraves computer but anywhere on the Range. Thus emerged what was later known as the General Remote Acquisition System (GRAS: pronounced 'grass').

John Rodger, who developed the digital acquisition system. After the joint project ended he took charge of the remnant Woomera trials component.

GRAS equipment was installed between 1960 and 1962 in the Tracking Data Centre (TDC) and terminal computers at various sites such as Red Lake, Mirikata and the four down-range Contraves sites. At the TDC, inputs to GRAS could be switched to take tracking data from MTS or the optical trackers, from either FPS-16 or from one of the local No. 3 Mk 7 radars, depending on which was likely to give the best track. There were two separate channels, so that acquisition aid could be provided for both missile and target in interception trials, for example.

The selected information in each was then converted as necessary so as to represent in digital format the Cartesian co-ordinates (referred to the rangehead) of the missile or aircraft. All sites served used the same two channels, unlike the Contraves acquisition systems, where angular pointing data were sent along separate dual channels to each of the three sites served (i.e. six channels in all), as the data could not be used elsewhere without parallax error. Many more separate channels would have been needed to extend such a system, and line transmission to distant sites was a major capital expense. At each remote site the GRAS information was corrected for parallax and then converted to polar synchro format suitable for the instruments at the site, just like the rangehead local acquisition system. Thus Contraves K27 for example could switch in acquisition and be automatically guided by a selected source, say R38 at Red Lake some 98 kilometres away, until such time as the operators spotted the distant missile in their eyepieces and took over. Alternatively one FPS-16 could guide the others.



The synchro gearbox of a GRAS acquisition system.

Following the flurry of activity from 1959 to 1963, the TDC settled down to using the Blue Streak/Europa equipment in more routine trials, of which there were many in the early 1960s. The next major change did not come until early in 1974, following a review of what to do with the range instrumentation now that trials work was clearly on the wane. The Tracking Data Centre was scrutinised closely; a lot of its equipment was getting old. The DIP, which had passed its tenth birthday, was still going strong—it fact it had grown more reliable with age—but programming and maintaining it took a lot of skilled labour. Also replacements for its individual germanium transistors were becoming unobtainable.[23] The decision was to strip out almost all the equipment in the TDC and replace it with a modern digital computer and displays. Eventually this was done, although it took almost as long as building DIP. This time there was no question of WRE's building the replacement computer; the main problem was securing the funds to buy what was needed.

The more modern look of the Tracking Data Centre during the last few years of the joint project.

The proposal was first broached with the Technical Committee of the joint project board in January 1971, which decided that both partners would contribute to a working party. This supported the WRE proposal for a commercial computer, at an estimated cost of almost a million Australian dollars if bought; the working party, however, favoured hiring in order to allow updating as needed, and because delivery would be faster. After more delays, in September 1972 a contract was awarded to IBM for hire of a system based on the IBM 370/145 and two smaller System 7 computers, initially for two years from date of delivery, which came in mid-1973. Preparations and testing at Salisbury swallowed more time, and it was not until January 1974 that the system was finally installed in the TDC, nearly four years after it had been first proposed. It was only then that the TDC took on the appearance of a modern data-processing room, with the only obvious relic of the analog days being a half-circle array of vertical plotting tables and some racks of terminal and recording equipment in the adjoining room.

Even then the ageing DIP—whose design was now fifteen years old, an eternity in computer evolution—got a short reprieve. Until the new system and its software had been thoroughly checked out DIP continued, its longevity a tribute to the skill of its designers.

The decision to hire rather than buy the IBM computers was a distinct embarrassment to WRE in the last years of the project. Had the equipment been owned by the project then probably it would have survived the run-down and become Australia's property.[24] As it was hired, WRE wanted to return it after the end of the main program of interception trials in 1975 to save hire charges of nearly $30 000 each month. This would have left WRE with a gutted TDC, incapable of navigating aircraft or displaying missile positions for the simplest trial.

There was, however, a temporary reprieve. Britain wanted to finish a last series of high altitude trials that needed the IBM 370/145, and was prepared to pay hire charges until they were finished. INS Group made the most of this by feverishly examining, with sympathetic help from the IBM experts who stood to gain little profit from it, just what could be done to salvage a very modest and cheap system for future real-time data handling, enough to navigate aircraft, and display present position only (no impact predictors). The 370/145 was out of the question, but there were the much smaller System 7 computers on which there was an option to purchase. So in June 1979, after the British had finished their trials, WRE retained one System 7 and IBM removed the rest of the hired equipment. A year later an IBM Series 1 computer was added to act as a data logger, and both were bought for quite a modest price, far less than the total hire charges of nearly two million dollars over six years for the previous system. There were other changes to the TDC to fit it for its post-project role, in which it was to be not merely a data management centre, but the control room for all future trials.

TELEMETRY

The word 'telemetry' is derived from two Greek words meaning measurement at a distance, and it is a technique much used wherever there is a need to transmit information from an inaccessible to a more accessible point. The use of telemetry is by no means restricted to missile ranges: it is quite common in industrial applications, for example to monitor conditions inside a blast furnace. But in such cases transmission is typically by wire, whereas radio telemetry is now universally employed to measure what is happening inside flying missiles and rockets.

As many as nine distinct telemetry systems were used at different times, most of them originating in Britain but much refined in Australia. In fact until about 1956 virtually every project had its own system. By the early 1960s the Range had made standard a particular Type 465 system for normal work, and for special applications a wide band Type 450. Even so, some large projects, particularly ELDO's Europa I, continued to have their own special arrangements. In the later years, the telemetry provisions shrank down to a combination of the 465 and 450 known as Type 4650, and finally to almost nothing at the end of the project.

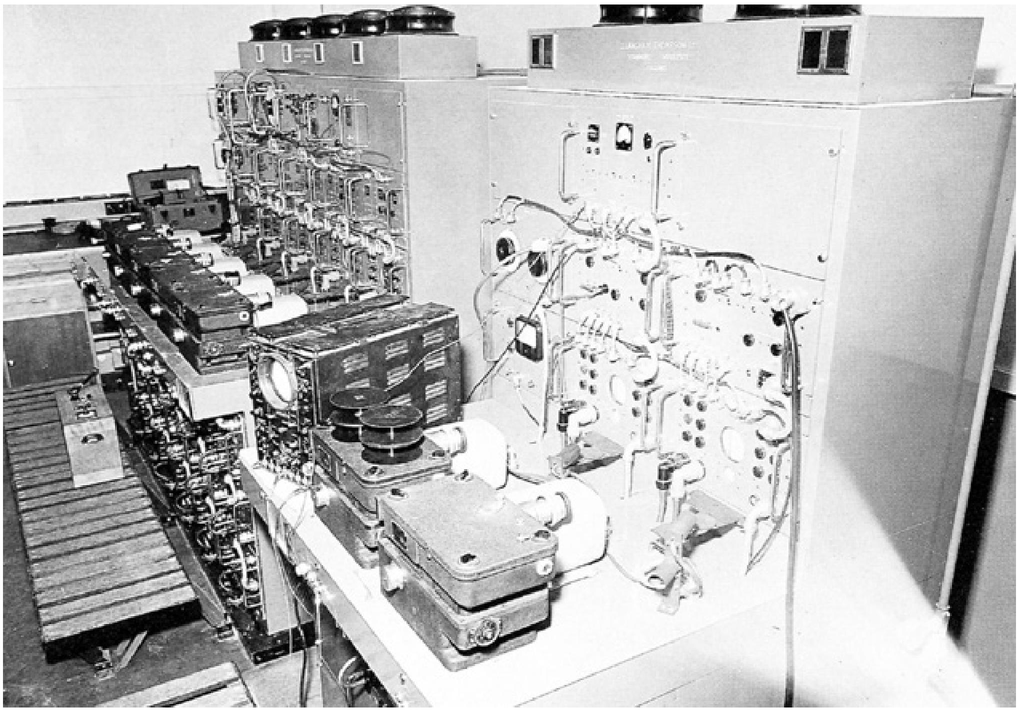
These systems differed in detail very greatly, reflecting different requirements and their designers' idiosyncrasies, but they all had the same basic elements. Inside the missile, aircraft or bomb were many transducers—accelerometers, thermocouples, strain gauges, pressure and vibration pickups and the like—whose purpose was to convert a physical quantity into an electrical analog such as a voltage or a frequency. All the transducer outputs were fed to a multi-channel transmitter, where the channels were multiplexed to share the same carrier wave. It is the same principle by which Telecom squeezes many telephone conversations down a single line or radio link.

On the ground the signal was received and, usually but not always, fed to a demultiplexer to separate the channels. Finally the telemetry data was recorded: by cameras photographing video displays in the early years; by tape recorders later on. The recording incorporated timing signals to allow correlation with other records. In order to interpret the record correctly it was of course important to know just how it corresponded to the inputs to the transducers. This could have been done by applying known pressures or accelerations or whatever to the transducer and noting the effect on the record, but it was much more convenient to calibrate the transducer and the receiving system separately.

EARLY TELEMETRY SYSTEMS

The oldest and simplest but not the first telemetry system to be used at Woomera was known as the RAE X157, developed in about 1944 for use in aircraft trials, including the experiments with the Barnes Wallis aerodynamic models over the Scilly Isles range in 1945-48. It allowed for the transmission of six channels of data.[25] The X157 system was first used at Woomera in 1951 for the Fairey VTO trials at Range E, and two senders were fitted to give twelve channels in all. But X157's main contribution to Woomera came with its adoption as the standard telemetry system for the pilotless Jindivik, Meteor and Canberra target aircraft. It sent to the ground all the information needed by the pilot: air speed, altitude, engine speed, acceleration and compass reading. The ground receiving station was initially in mobile vans at the Range E rangehead from 1952, but by early 1955 this equipment had been moved to the new Flight Control Centre building at Evetts Field. Through many further upgradings the X157 telemetry system persisted as a permanent part of the target aircraft service. Australia contributed many of these improvements: for example, the transducers were developed by GAF Melbourne for their Jindivik and were manufactured by local industry.

Another 'special to project' but short-lived system was that known as TRE telemetry, named for the Telecommunication Research Establishment at Malvern which developed it, or alternatively as the Type 600 after its 600 megahertz carrier frequency. Actually it was not one but two separate systems: a six-channel voltage telemetry and a single channel roll telemetry, measuring the missile's rate of roll around its long axis.[26] Voltage telemetry was only ever used for one series of Woomera trials, the CTV5 trials at Range E from 1953 to 1956, and as we have seen in Chapter 1 they were not notably successful. The rather complex TRE telemetry was partly to blame; it was neither very reliable nor very accurate. Nothing more wasdone with the voltage telemetry, but the simpler roll telemetry lasted some years, after



Type 600-voltage telemetry equipment in the Instrumentation Building (1953).

some local work around 1954 to convert it for use with yet another system that was by then becoming standard at Woomera. This was known originally as the 'RAE subminiature' and later as Type 465 telemetry.

TYPE 465 TELEMETRY

Grahame Lister

Paul Gillard

The origins of Type 465 went back to a 24-channel system that was being developed, at about the time when Woomera was being built, by a MoS station known as the Signals Research and Development Establishment (SRDE) at Christchurch, a genteel resort on the south coast of England. This SRDE system was the first telemetry ever devised in Britain for guided missiles, and was intended specifically for RTV1 trials at Aberporth and Woomera.

This early SRDE system was a time sharing system like the TRE Type 600. It had twenty-three channels rather than six, but each channel was sampled not 2000 times each second but only forty. It was only useful for telemetering slowly varying quantities, but it had the advantage of being considerably simpler than the other system. The sender in the missile included a motor driven mechanical switch or commutator to sample the channels in turn, which is the simplest way of multiplexing.

In the ground station the display appeared on a large video screen and photographic recorder known as the '24 by 30 inch'. Development of the SRDE system was well advanced in 1948. By then RAE had been given the task of producing telemetry senders that would fit into missiles as small as 127 millimetre diameter. The SRDE senders were designed for RTV1 which was twice this diameter, but time was to be saved in meeting the new requirement by suitably modifying the existing system. It so happened that from May 1948 three of the second batch of Australian trainees were working at an RAE outstation near Farnborough, which occupied a pleasant former golf clubhouse at Bramshot. One of them, Grahame Lister, was given the job of designing the miniature sender. Another, Paul Gillard, later took over the work of adapting the SRDE ground equipment. The third trainee, Brian Deegan, was afterwards assigned to the SRDE and RAE X157systems.

Gillard later recalled that when he was interviewed for a traineeship in 1947 he had never heard of telemetry and had to look up the word in the dictionary beforehand. He got the distinct impression that the interviewing panel knew little more than he. Soon after he and Deegan arrived in England they were invited to TRE and RRDE at Malvern, and he recalls their being shown an early project involving a digital communications system known as pulse code modulation:

This, of course had some relevance to telemetry, but I am not sure that I appreciated it at the time. I particularly remember, after this whirlwind tour of the activities of those two establishments, getting into the car and sitting quietly beside Brian Deegan. We said nothing for quite a while, and then I think Brian made the move and said to me, 'What is pulse code modulation?' I replied that I wasn't quite sure, but I thought it had something to do with binary numbers to the power of two. That was in early 1948, but it makes one realise just how raw we were.

But they learned quickly. One of Gillard's first steps was to visit the SRDE team at Christchurch with the aim of borrowing one of the four sets of equipment that had so far been produced. He recalls his first meeting with the team leader, Phil Jewell, and his offsider, Eric Husbands, in their large laboratory at Steamer Point overlooking the beach:

I could hardly see the two of them seated at the far ends of two or three tables stacked together, because of the smoke. And every question that I asked led to one, two or three draws on pipes by both of them, with swirls of smoke going to the ceiling, and then a very carefully measured reply, in which Phil Jewell in particular covered every point that he made with all the exceptions and the conditions under which it might apply. A very pedantic approach, I seem to recall, which I later found was reflected in the design of the system. In fact I remember him explaining to me in great detail . . . his reason for using a very, very expensive ship's chronometer on the front of the equipment to ensure that the timing was right. (There were no time code generators in those days.)

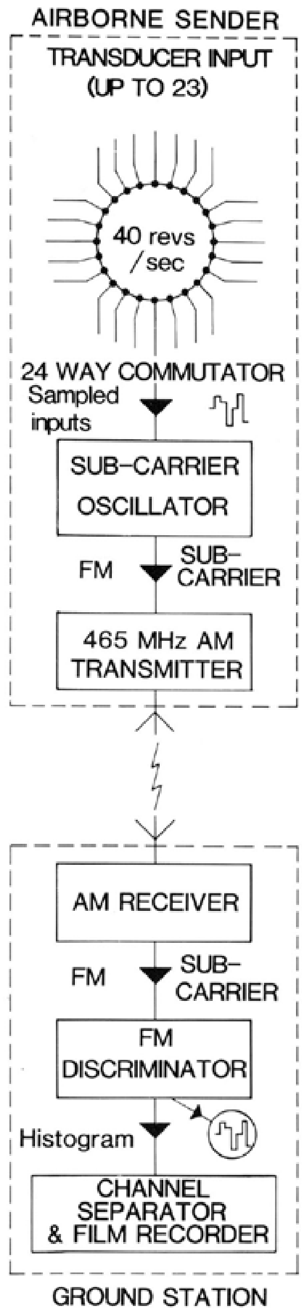
Gillard returned to Bramshot with one of Jewell's sets of ground equipment and spent the next eighteen months redesigning it to work with the new subminiature senders that Lister was busy developing, while still working with the existing SRDE versions. One of the aims was to speed up the sampling rate, but at that stage nobody knew how fast the miniature mechanical commutators could rotate and still have a reasonable life. ('Reasonable' in this context meant ten minutes at least.) So the system had to accept a wide range of sampling rates. The nominal sampling rate eventually adopted was 80 per second for each channel, twice the SRDE rate, but this could be varied between 40 and 120. The sender components had to be small, and even the smallest valves then available were large indeed by modern standards; but Lister found that specially selected tiny valves made for VT fuzes would work in the critical FM modulator stage.

Eventually after a lot of hard work, including two weeks of seventy to eighty hours each, the time came for the first trial of the new RAE subminiature system, as it was called. Gillard's receiver van was towed to the Larkhill firing range on Salisbury Plain, and five inch sighter rockets were fitted with Lister's senders. As Gillard recalled it:

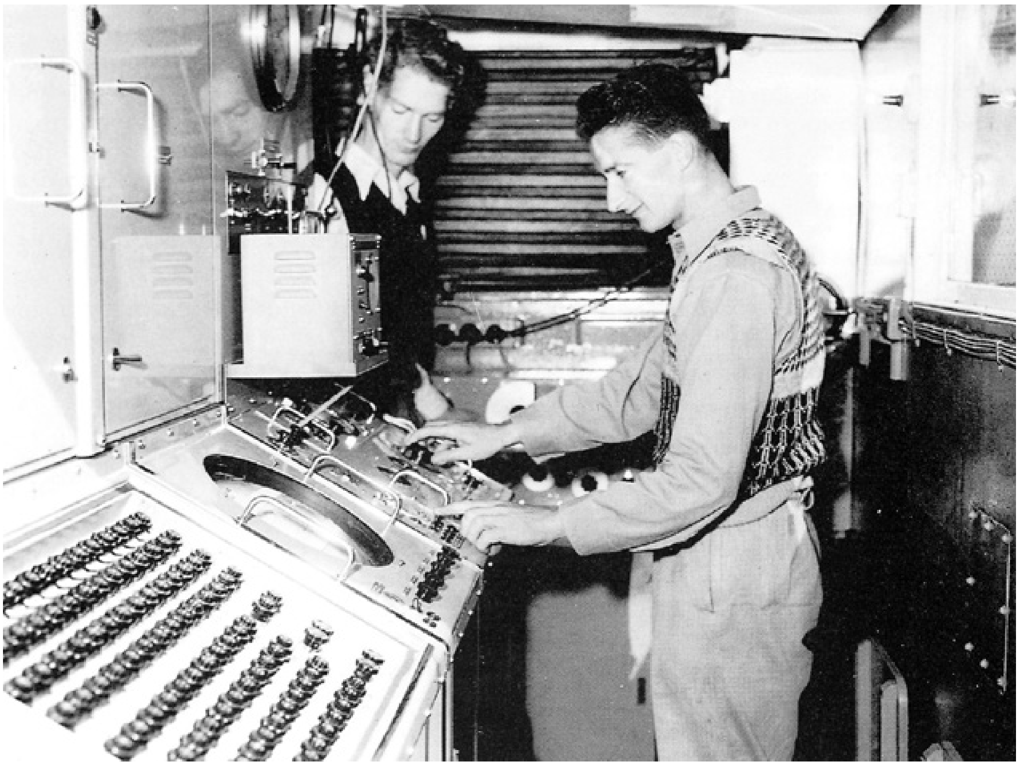
The firing sequence depended on Grahame [Lister] having to give the OK when the umbilical cord was removed from the missile, to confirm that the telemetry was successfully operating on its internal batteries, and this would have been some seconds before the planned lift-off time. He was standing beside me looking at a large 12 inch display tube with the histogram on it. When this key event occurred, the picture vanished and Graham yelled 'Wait, Wait, Wait' in his broad Australian accent. This was interpreted as being 'Right, Right, Right' and off the thing went. That was the first attempt at testing the subminiature telemetry system. Well, we had quite a number of successful trials after that.

The RAE subminiature was actually the first telemetry system to be installed at Woomera; it went in at Range G soon after Gillard returned from his traineeship early in 1950.

It was now the turn of the original SRDE telemetry system to make its appearance at Woomera. Jewell and Ken Knight of SRDE had come out to get it operating and hand it over to LRWE. They were assisted by Deegan, who had returned to Australia earlier, and others of LRWE. By November 1950 it had been commissioned at Range G and it was successfully used on the first RTV1 firing in Australia in November. One of those involved in these early trials, Don Freeman, recalls with a certain amount of nostalgia the SRDE sender used on the RTV1s as it was his task, as part of Brian Deegan's team, to prepare, check out and calibrate the sender before flight. The sender, which was in fact the pointed nose cone of the RTV1 missile, was constructed of a large almost solid brass casting into which the electronic units were recessed, with the whole enclosed in a heavy screw-on steel cover. A lead acid battery in the base powered not only the telemetry system but the control system on the rest of the missile as well. It took two men to lift, locate and bolt this device onto the rest of the missile.



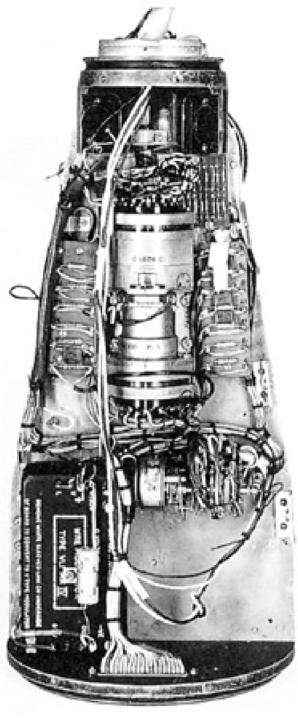
The 24-channel time-sharing SRDE telemetry. In the airborne sender, each transducer was sampled in turn by a motor driven commutator, and it controlled the frequency of an FM sub-carrier which in turn amplitude modulated a transmitter. These processes were reversed in the ground station. From this system was developed the Type 465 telemetry.



Setting up the low speed recorder in the SRDE telemetry van at Range G. in 1951

The final scientific test on the sender was to take a stout length of jarrah post and, with all systems running on the internal battery, deliver a series of hefty blows to the top end of the sender. If it passed that test it was good enough to go to the launcher.

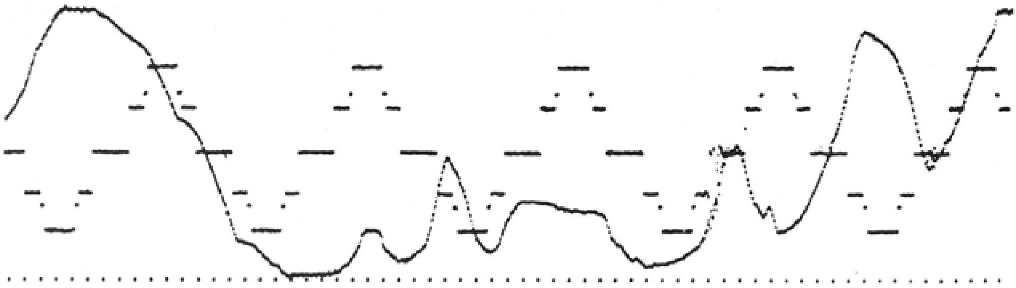
The SRDE telemetry system was used only in the RTV1 series of trials which ended at Woomera in 1956. During its six years of use various changes and modifications were made to the vehicle-borne equipment, including the use of the LRWE medium-power oscillator developed for the RAE subminiature telemetry system. The ground equipment was however virtually transformed to make it compatible with the RAE subminiature system. In fact, the only original SRDE items left were the display units and the '24 by 30 inch' low speed recorders, which became an enduring SRDE bequest to the RAE system: they were still in use until the mid-1960s. In this way the SRDE equipment effectively lost its separate identity and merged with the RAE subminiature.



A 1966 photo of a Type 465 telemetry sender, showing the commutator and VL1 modulator.

In the meantime further development of the subminiature system (by now called the 'RAE and LRWE subminiature system') was proceeding at Salisbury under Gillard's very active leadership. He had taken over the senders as well as the ground equipment when Lister was promoted to be head of the Group soon after his return to Australia in 1951.[27] By 1953 Gillard had developed for the subminiature senders a new high power transmitter and a new modulator, the device that converted the switched transducer outputs to a frequency modulated (FM) sub-carrier signal. In the process the design of the whole system was tidied up, especially as physical quantities such as acceleration and pressure now had to be measured more accurately. Accordingly the new modulator was much more sophisticated and stable than the RAE version.[28] The first hundred modulators were manufactured in 1953-54 by EMI in Sydney and used printed circuit boards for perhaps the first time in Australia. The new transmitter and modulators formed with the EMI commutator the basis of the telemetry senders that were used in RTV1 and most other missiles over the next decade.

The SRDE and RAE telemetry ground equipment was originally installed in two vans, which simplified the shift from Range G to Range E when RTV1 trials were transferred there. They were joined by a van containing the TRE 600 megahertz equipment, and the three responded to the intercom call signs of TELEDOG, TELEFOX and TELETREE. By mid-1955 all the van equipment was located in permanent quarters in the ground floor of the Instrumentation Building, where there was lots more room to work in and to expand in future.



Portion of a telemetry photographic record.

PROCESSING TELEMETRY DATA

Up to 1956 all the telemetered information was recorded on film, and reading the many wiggly lines by eye in these lengthy records was obviously a long and tedious process which still had to be done before the next firing could take place. Thus there was great pressure to automate the analysis. As we will see in Chapter 19 there was a co-operative effort by WRE to develop a system suitable for the new digital computer, WREDAC, which required the analog telemetry data to be converted to digital format. The conversion could have been done by a semi-automatic film reader like the Boscars used for reducing kinetheodolite records, but there was a general preference for a fully automatic procedure. Accordingly, magnetic tape recorders were added to the Type 465 ground equipment at Range E, and in March 1956 the first fully integrated trials data-processing system began, well ahead of Britain and even America. The quarter inch tapes from the Range were sent to Salisbury after the trial and played back at lower speed so that the analog telemetry data was fed into the data converter along with a recorded reference frequency (which corrected for wow).[29] This converter produced a secondary tape in digital format which could then be fed into WREDAC. The final product was a printout of columns of figures of calibrated data. The photographic recorders remained, however, as users had found they could 'read' the lines directly to see how their missile had performed. But they no longer had to measure them laboriously by eye.

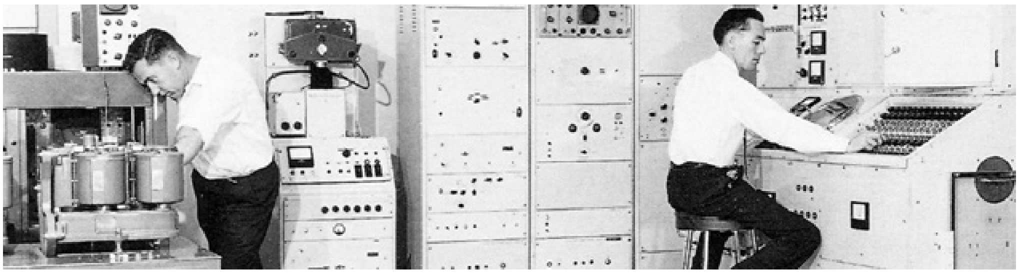
There was a valuable side benefit that emerged from this successful automation. The '24 by 30 inch' low speed recorder was difficult to set up, not only mechanically but because of the complex channel strobing needed to demultiplex. It generally took much longer to do this than to adjust the receivers and other equipment, and often it was the telemetry station that was holding up the Range. With the tape recorders operating satisfactorily it was found possible to forget the photographic recorders during trials. Instead the tape record was played back into the demultiplexers and photographic recorders afterwards, when there was more time to set up.

The quarter inch tape recorders were replaced by Ampex FR107B machines in 1961. Two years later a much faster transistorised Mk 2 data converter went in at Salisbury in place of the valve type Mk 1 version.

TELEMETRY REPLAY AT SALISBURY

Now that photographic telemetry records could be reproduced at the Range after the trial by playing back the magnetic tape records it was a small step to transferring this replay work to Salisbury, in line with the policy of doing as much as possible there for economic reasons. The tape records had to go to Salisbury anyway for data conversion. The main photographic processing facilities were there, and Range users who wanted the photographic records were generally based at Salisbury.

A telemetry replay station was first set up temporarily in 1959, in the same building as the processing labs run by Range Support Group, which also operated and maintained the replay station. It became a more permanent facility in early 1962. Recorders used with the Type 465 system were installed, including the large low speed '24 by 30 inch' recorders inherited from the old SRDE system, and 5½ inch and 35 millimetre high speed recorders. The tapes were played back into demultiplexers and thence into these recorders to display the separate channels as wiggly lines on the record. By the end of 1962 the facilities had



The Salisbury telemetry replay station in 1963. The 24 x 30' low speed recorder is on the right.

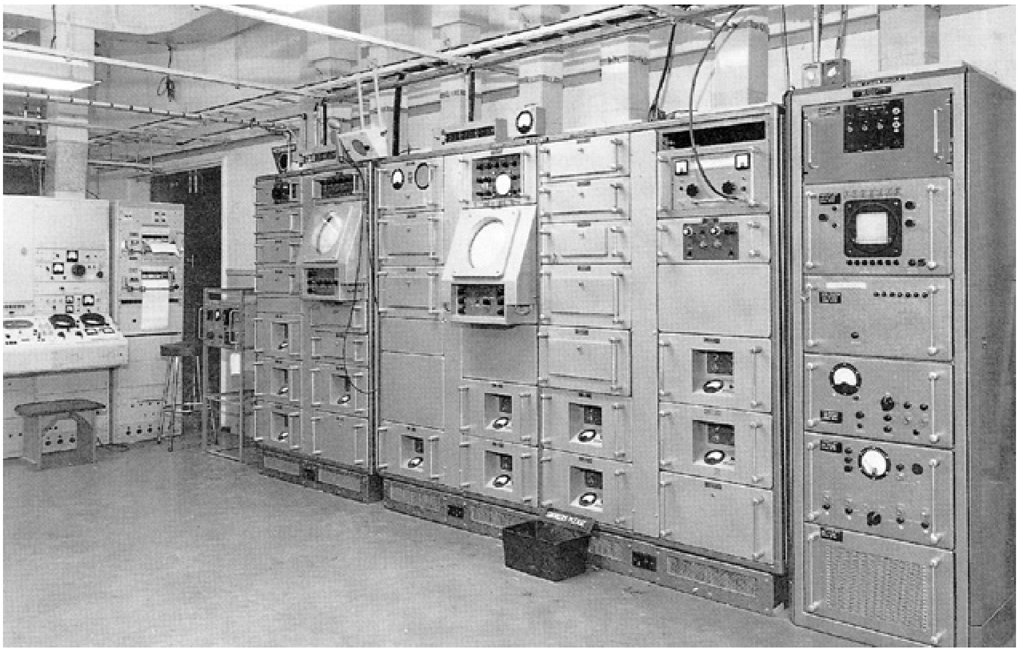
been extended to cope with broad band Type 450 tapes as well as Type 465. The third phase was to equip the station afresh to take the 4650 system, and this was done by early 1967. The multiplicity of photographic records was replaced by the 34 centimetre wide continuous records from the Type 630 recorder that had been supplied with the Type 450 telemetry system and adopted for the Type 4650. Range users accustomed to the old '24 by 30 inch' low speed recorder regretted its passing, as the new 34 centimetre wide, slim look recorder, despite many other advantages, could not conveniently display all twenty-three channels.

The Salisbury replay station remained until 1976 when it was dismantled early in the run-down. For a while any necessary replays were carried out at the Range.

Three auto-tracking TAFE aerials and a slave on the Instrumentation Building roof.

TAFE

With longer range trials looming in the mid-1950s, a more sensitive receiving aerial system was needed, so Gillard's telemetry team co-operated with the electronic tracking experts in developing a highly directional array that would track the missile. The first attempt in 1955 used a parabolic dish reflector on a Bofors gun mount, slaved to local radar or the MTS, but this was considered unreliable as it was completely dependent on good track from the master instrument. So it was decided to make the telemetry aerial do the tracking itself, in the same way as radar and the MTS did. Taking the lead in this development was Bill Mettyer of EI Group. Once again the ubiquitous No. 3 Mk 7 radar mount was pressed into service, and this time it was fitted with twelve protruding helix aerials, which tracked automatically by using a beam-switching technique. There were one or two false starts, but by 1959 the new Telemetry Auto Following Equipment (TAFE) had been successfully used in trials. Black Knight was an early success and in fact there were attempts in 1961 to use it on these trials as a source of acquisition data for Contraves kinetheodolites and other tracking instruments, as we will see in Chapter 21.



Ground equipment of the Type 450 broadband telemetry system.

Later TAFE was developed further to include a large high gain slaved version. By the late 1960s there were three TAFE and two slaved tracking aerials adorning the roof of the Instrumentation Building and two TAFEs at Mirikata. But not all were used for the Type 465 telemetry, as by then several other telemetry systems had appeared at Range E.

TYPE 450 TELEMETRY

First to arrive in the 1960s wave of new telemetry systems was the SRDE Broadband Telemetry, later known as the Type 450 from its nominal 450 kilohertz radio frequency. Its development dated from the early 1950s, when SRDE turned to it after RAE had taken over the further development of their twenty-four-channel 465 megahertz telemetry. The RAE subminiature system fitted the smaller missiles, but at the cost of a restricted bandwidth—it could not cope with rapidly changing transducer outputs. The TRE 600 system could, but it had not proved a success. So Jewell and others of SRDE set out to develop a wide band system, with considerable help from the British firms AEI and GEC. The result could carry data at a much faster rate than the Type 465, but the size of its sender limited it to missiles the size of Bloodhound or larger.

The Type 450 was a time-sharing system like the Type 465, but it had a much higher sampling rate. Its seven data channels were sampled electronically about 8000 times a second. Channels could easily be multiplied by sacrificing the fast response, which was usually only needed for vibration transducers anyway. Up to four HF channels could be 'sub-multiplexed' by a motor-driven mechanical switch similar to the one used in Type 465 senders: it sampled each of the twenty-one available data inputs about 120 times per second, providing up to eighty-four medium frequency channels and still leaving three HF channels for high frequency vibration data if needed.[30] There was also a choice of three different transmitting modes, known as Schemes A, B and C, with corresponding ground equipment.[31]

By 1961 the Type 450 ground equipment had been installed by visiting SRDE staff, with two sets in the Instrumentation Building alongside the Type 465 and one in vans at the Mt Eba site. They had been designed from the outset for magnetic tape recording, using four fast (75 in/sec) sixteen track tape machines to record the HF channels on one inch wide tapes. However a cathode ray type 'pilot recorder' could also be used to produce a 13.25 inch wide photographic record of these HF channels, either at the time or afterwards by playing back the tape record. The existing Type 465 equipment was used to record the sub-multiplexed MF channels.

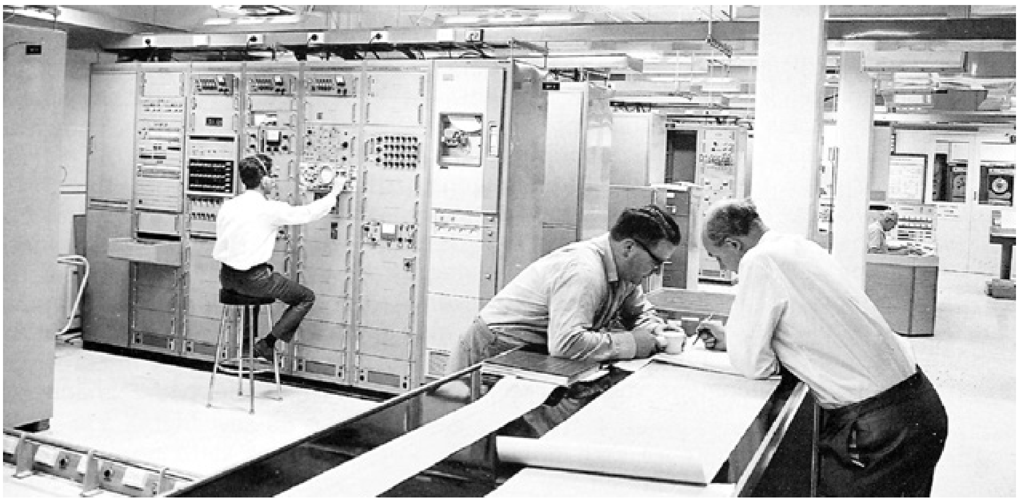
PROJECT TELEMETRY REAPPEARS

ELDO's big satellite launcher project introduced two special telemetry systems to the Range and to the Gove tracking station in the far north of Australia. While the Blue Streak first stage of Europa was British and naturally enough was fitted with normal Type 465 senders, the upper stages were supplied by other partners and they carried other systems. The French second stage used Nord Aviation Ajax telemetry, a French version of the American IRIG system.[32] Holland contributed the telemetry for the third stage and satellite, and it was a Philips system in which the data were converted to a digital code and transmitted as an FM signal. As might be expected, both these systems needed special ground equipment, and this was installed in the Instrumentation Building and at Mirikata in time for the first Europa firing in its full configuration (F4, launched in May 1964). Later the Dutch receiving equipment was installed at the Gove station in Arnhem Land for the orbital attempts.

Another 'project' telemetry system was used in 1966-67 for the Sparta trials, a co-operative UK-US-Australian program of re-entry research which was effectively a successor to Black Knight. The missile was an American Redstone with solid fuel upper stages, and naturally the telemetry was one of the standard IRIG systems used on US ranges: in this case a frequency multiplexed FM/FM system. The US Sparta team installed the telemetry ground equipment. It was Sparta's modified Redstone that launched Australia's first satellite, WRESAT. On that occasion, as well as the IRIG equipment for the Redstone, there was yet another special telemetry receiver station to monitor the sender in the satellite itself, which was compatible with the world-wide network of NASA tracking stations. After WRESAT the Americans bequeathed their IRIG system to WRE and it remained at Woomera.

CONSOLIDATION

By this time Gillard and his British counterparts had been working for many years towards a standard telemetry system for use in trials in both countries. Type 465 had been favoured in the 1950s, but as we have seen earlier it was not suitable for high frequency data channels, and the Type 450 had been adopted to fill this niche. Since the late 1950s much thought had been given in both countries to a possible successor to the Type 465 subminiature system. Already missiles were being fitted with two senders and versions in which forty-eight channel switches replaced the original twenty-four channel type, in order to cope with the demands of the bigger missiles for more and more information. From 1962 a series of conferences was held alternately in each country to hammer out a co-operative program of work for the forthcoming system. Not surprisingly, MoS would handle the airborne senders and WRE the ground equipment. But the first step was to agree on the standards to be adopted, which would have to provide for a flexible choice between many channels and wide bandwidth. From this emerged proposals for what became the 4650 system, which in effect combined the advantages of Types 465 and 450.[33] With considerable help from a team of engineers in Electronics and Communications Division led by Innes Renton, the 4650 ground equipment was developed, built and installed, and it was in service by March 1967.



The telemetry room at Range E, showing part of the 4650 ground equipment.

RUN-DOWN

The 465 and 4650 equipment served the Range well for the next decade or so, as it was flexible enough to cope with any demand. After the ELDO program finished in 1970 it was the only operational telemetry other than the IRIG left over from Sparta. When the British decided to pull out of Woomera altogether in the late 1970s the 4650 telemetry had no future, because it would only work with British senders (except possibly for a few Australian trials for which WRE's Aeroballistics Division (AD) had in the past provided Type 465 senders). So the hard decision was taken to pull out all the telemetry gear apart from two slaved tracking aerials and some recorders. Should telemetry be required in future (as it occasionally was), then the Range user had to supply receivers and demultiplexers to suit his senders. The decision was not popular with AD, but at least they secured much of the surplus Type 465 receiving equipment which could be pressed into service for the very infrequent post-joint project trials requiring telemetry. Thus the telemetry room in the Instrumentation Building, which apart from the Tracking Data Centre had been the Range's largest and busiest area during trials, shrank to less than a third of its former size.

Notes and Sources

1. It should be borne in mind that the distinction between 'optical' and 'electronic', though useful, was somewhat artificial. Some of the optical tracking instruments, especially the Contraves kinetheodolites, employed advanced electronic circuitry for tracking control and timing. The distinction was reflected in the organisation, though. From 1955 to 1962 an Electronic Instrumentation (El) Group at Salisbury developed the systems described in this chapter. In 1962 El Group was split in two, with Electronic Tracking Systems (ETS) taking over radar, MTS, doppler and tracking data, and Telemetry Systems (TMS) taking telemetry and also timing. There was a corresponding reorganisation of the old Electronic Instrumentation section of Ranges Group at Woomera.
2. A radar transponder is a device fitted to the flying target that receives the pulse from the radar, amplifies it and re-transmits it, usually on a different frequency. Apart from enhancing the strength of the echo signal, it also reduces the sharp drop in performance with distance to be expected for 'skin' tracking without a transponder. In such cases an inverse fourth power law applies: doubling the range drops the power of the echo signal received at the radar to one sixteenth of what it was. For transponder tracking an inverse square law applies: doubling the range reduces the received power to one quarter.
3. The kinetheodolites were not designed to produce data output in real time; nevertheless one or two Askanias and Contraves were modified to do so.
4. There were other radars at Woomera in the 1950s, but they were either guidance radars used with specific guided weapons systems, such as the GMY(1) radar for Seaslug, or surveillance radars like the early AMES XI or the later No. 4 Mk 7.
5. The Austrian physicist Christian Doppler first explained this phenomenon in 1842. By comparing the pitch of a moving bell with a stationary tuning fork, he showed that the change in frequency is directly proportional to the radial velocity of the source relative to the observer.
6. Strictly, the doppler shift in frequency was proportional to the rate of change in path length from transmitter to missile and back to the receiver. Each time this return path changed by one wavelength of the transmitted signal, the doppler beat note went through one cycle. Thus one could count cycles to measure path length changes, and timing them gave the radial velocity.
7. See LRWE reports T/T 1, '4" rocket trials: first report' and T/T 3, '4" rocket trials: second report'. DRCS Library refs SWM-38213-U and SWM-38215-U. The three transmitters used different frequencies to avoid interference.
8. It was not practicable to use the known launcher position as a fix, since the doppler took a few tenths of a second of flight to start recording a measurable signal.
9. 'Doppler Test Vehicle (DTV)'. LRWE Technical Memorandum C/M1 (February 1950). DRCS Library ref SWM-38200-U.
10. On a spinning missile the transponder aerial was spinning too, and this generated a changing phase shift which introduced errors into the measurement of the distance that the radio waves travelled. Corrections were normally made during data reduction by applying a formula based on measurements of spin rate, but Dr M. L. Lees of INS Group showed that sometimes the errors could not be corrected. He developed a method of manually editing doppler tapes to remove faulty data, but it was very laborious and prone to human error. See M. L. Lees & S. L. Crouch, 'Editing doppler tapes to remove the effects of missile spin'. WRE Technical Note 961-T. DRCS Library ref SW-M-21396-U.

11. Originally Britain was to pay for the sets under the Dalton formula, but as the Sandys agreement of 1953 came into force before they were supplied, Australia ended up paying half: its share was £87 500 for the five sets.
12. A third FPS-16 radar supplied to the UK by the US under this agreement was installed at the Aberporth range.
13. From August 1974 to October 1978 there was also an arrangement with the US Air Force to share in the Depot Level Maintenance agreement, under which RCA supplied spare parts for the FPS-16s.
14. Two Yellow River radars had been installed in 1957-58 as target illumination radars for these semi-active homing missiles. They were no longer required after the trials finished in 1960, as the succeeding Mk 2 Thunderbird (VR725) and Bloodhound trials needed a different CW type radar. The two Yellow River radars were removed in September I960: one was shipped to UK. The other went to Singapore but it was subsequently returned.
15. R. L. Birch and J. G. Rodger, 'Short Range Plotting Facilities: Woomera Missile Range'. WRE Tech Note E1D29 (July 1959).
16. The margin between cut-down and impact limit lines was previously calculated to allow for errors in predicting impact, and for reaction time and other possible delays, under the most pessimistic assumptions of a misbehaving missile. The allowable risk of impact outside the limit lines was a conservative one in a thousand.
17. Working at 1200/2400 bauds, this system was fully transistorised and incorporated Hamming double-error-detection and single-error-correction coding.
18. Anecdote of Emlyn Jones at an interview in July 1985.
19. Contribution of G. E. Barlow dated October 1984. Much of the information on DIP is drawn from this account.
20. Reminiscence of Peter Twiss at an interview of 31 January 1985.
21. Jones.
22. Information in a letter from G. E. Barlow dated 8 July 1985.
23. DIP was programmed in machine language rather than the easier to use higher level languages such as Fortran used by more modern machines. It also had few diagnostic facilities to help in finding faults.
24. This was in accordance with the 1976 joint project renegotiation, subject to Australia taking over responsibility for upkeep and to the UK receiving half the proceeds if sold on disposal.
25. The FM sub-carrier signals in six different bands were all carried on the same AM radio transmission (90-95 megahertz for the Australian equipment, but this was later shifted to the higher UHF band). The transducers were inductance type, and each formed part of a resonant circuit tuned to its assigned band, so that a change in the input physical quantity gave a corresponding frequency change in the sub-carrier.
26. The TRE 'voltage telemetry' was so named because it was designed for transducers with voltage analogs outputs. The six were sampled in turn in the missile, 2000 times a second for each so that rapidly varying quantities could be telemetered. The varying voltage samples were then converted to time analogs by controlling the individual time delays in a train of very short pulses (a system of time sharing known as 'pulse position modulation'). After transmitting by radio to the ground receiver and demodulating, the pulse trains were separated into the six channels and recorded by photographing a cathode ray display. The TRE 'roll' telemetry radiated a simple unmodulated carrier from a dipole aerial aligned perpendicular to the missile long axis. The receiving aerial was placed to the rear of the launcher, ideally just behind its line of flight, and this aerial was a rapidly spinning dipole, mounted at right angles to the spin axis, like a twirling baton (or propeller). The output signal strength was recorded, and because of the spin it varied from a maximum when the two dipoles were parallel to a minimum when at right angles (because of plane polarisation effects). Also recorded were timing pulses and marks to indicate when the receiving dipole was at its 'zero' position. The roll of the missile about its long axis could then be measured by computing the angles of the receiving dipole for successive nulls in signal strength.
27. Boswell had clearly singled out the very capable Lister for early promotion, and there is little doubt that he would have risen to very senior positions but for his untimely death in 1956.
28. This LRWE modulator was known as the 'VL1': 'V' for voltage and 'L' as the conventional symbol for inductance, as it was suitable for both types of transducers. It used a new type of stable subminiature valve—huge of course compared with the later transistors—with an indirectly heated cathode.
29. The Range magnetic tapes recorded the FM sub carrier before demultiplexing (translated down to lower frequencies to suit the recorders). As the signal was FM, the frequency was an analog of the telemetered data. On replay into the converter each channel was sampled in turn, during which an electronic gate opened for a fixed number of data cycles and the converter counted the number of cycles of the precise reference frequency passing through the gate. Thus the sampled counts were a measure of the original data, independent of recording or replay

speed fluctuations.

30. An eighth HF channel was reserved for synchronising and calibrating and three channels of each 24 channel MF switch were used for jitter correcting.
31. Scheme A used a direct frequency modulation of the main carrier, with no subcarrier. In Scheme B the FM sub-carrier amplitude modulated the main carrier, while Scheme C was a direct FM system in which the FM output of the multiplexer was translated and multiplied to produce the main carrier. Schemes A and B transmitted in the 420-470 megahertz band, Scheme C at crystal controlled frequencies in the 230-260 megahertz band. Scheme C had a higher power transmitter so could be used at longer ranges. J. S. Bell, 'Telemetry systems at Range E Woomera'. WRE Technical Note TRD 26 (July 1968).
32. The IRIG (Inter Range Instrumentation Group) Steering Committee, which represents most US military missile test ranges, sets up and maintains standards of US range telemetry and other instrumentation. The Ajax system had twelve frequency multiplexed FM/FM channels, three of which were PAM/FM/FM with time multiplexed inputs.
33. There were two separate telemetry systems of which the first was the 24 channel Type 465 and an associated 48 channel version known as '4650 variant 1' The other was a broadband system known as 'Type 4650 variant 2', and it provided 14 data channels each sampled 4000 times per second, and up to two of which could be sub-multiplexed.

16 Instrumentation 3: *The Nerves of the Range*

In this chapter we turn to the remaining members of the old 'electronic instrumentation' class: timing, sequencers, hazardous circuits and communications in its various aspects. These do not form so coherent a group as the optical and electronic instrumentation of the last two chapters. However, all of them transmitted, received and processed information or control signals over a distance and thus might be described metaphorically as the nervous system of the Range, along with telemetry and tracking data systems working in real time.

At Salisbury, communications and sequencer and hazardous circuits were generally regarded as engineering services for which engineers in Communications section were responsible. But at Range E they were lumped in with timing, so that in common parlance they were 'timing and comms'. This was more a shotgun marriage than a voluntary union, which had come about in 1951 when Communications section had taken over timing and had set up a single centre in the Instrumentation Building for all these services. They did have something else in common, though. Unlike the optical and electronic tracking systems which were all imported from Britain in the early years, timing and communications and the rest were of Australian design and production from the start. The only minor exception was the early timing and sequencing gear for Range A described in Chapter 10, which came from Orfordness.

TIMING FOR THE MISSILE RANGES

Timing was an essential service; so essential, in fact, that none of the other instruments could do without it. For example, the kinetheodolites had to be timed, not only to synchronise them but because the measurement of time was just as vital in computing trajectory as the angles that they measured, particularly when velocity and acceleration were to be derived. Similarly radar, MTS, ballistic cameras, AMPOR and the other trajectory recording instruments needed a time dimension if their records were to mean anything. Even the telemetry systems and Vinten cameras that recorded the internal and external behaviour of missiles were linked into the net of common time signals, so as to tie together events recorded at separate places and in different ways. Otherwise all the jigsaw pieces of information about the trial did not fit properly and the picture was a jumble.

When Boswell became head of the new Electronics Group in April 1948 he started to work at once on a source of timing signals for the forthcoming missile range. Britain was supplying all the other instruments, but the timing system was Australia's responsibility. Nothing remotely suitable was available commercially. Nor was Boswell's Electronics Group capable of building such a source. By September 1948 he still had only four staff and his laboratory was little more than an empty building, used for chemical testing in the days of the Explosives Factory. Without knowing just what would be needed, Boswell set to and wrote a specification for a versatile central source to supply uncoded timing signals at frequencies ranging from 1 hertz up to 1000 Kilohertz and with the shape of a pulse, a square or a sine wave. Such signals would be used to mark the records of cameras, chronographs and other recorders, from which the time relative to other events could later be read by counting the timing marks, to an accuracy of about a millisecond.[1]

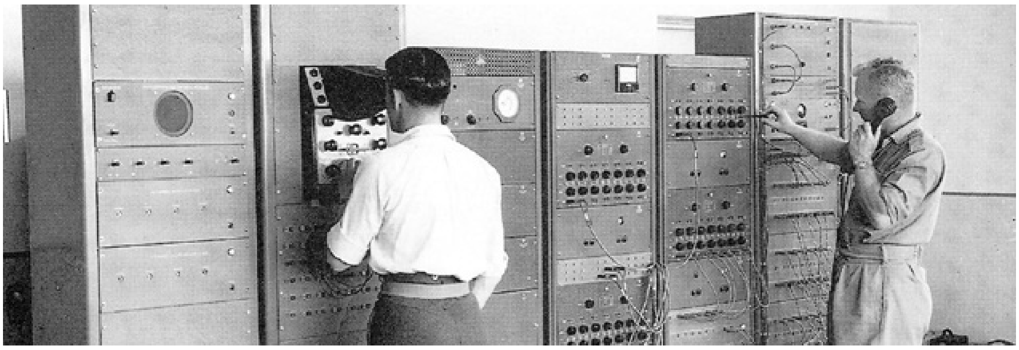
In September the Sydney-based electronics firm, Amalgamated Wireless (Australasia) (AWA), was awarded a contract to manufacture Boswell's unit. By May 1949 the Central Timing Unit (CTU) had been delivered to Electronics Group and tested. But by then the idea had emerged of synchronising the Askania kinetheodolites, as mentioned in Chapter 14, which involved modifying both the CTU and the kinetheodolites. In addition, every instrument site needed terminating equipment to receive and amplify the timing signals, which came through field cables. Electronics Group had expanded quickly in the meantime and was able to produce all the necessary extra requirements in time for the first serious missile trials at Woomera, which were the 4-inch LPAA trials at Range F in August-September 1949. The CTU, and LRWE's additions to it, were installed on the Range in a small van, and in another darkened van nearby was a hurriedly made chronograph consisting of an array of small mercury vapour lamps on a wooden frame, photographed by a recording camera. When Range G replaced Range F at the end of 1949 the CTU was moved there along with other instruments. In August 1950 a second almost identical CTU, also made by AWA, was installed at Range E in a vacant part of the Communications Building, along with LRWE's own additions as before. This second CTU was first used with the Fairey VTO trials in 1951.

Although the CTUs were only prototypes and LRWE's additions frankly experimental lash-ups, they both performed well. Electronics Group and AWA went on to specify a refined version that included the special 4 hertz timing pulses which synchronised the Askania kinetheodolites. The Mk 2 version of the CTU was however to be a dual unit, with the extra timing source serving as a back-up. In other respects Boswell's concept of a central, versatile source of timing signals survived in all later versions of the CTU.

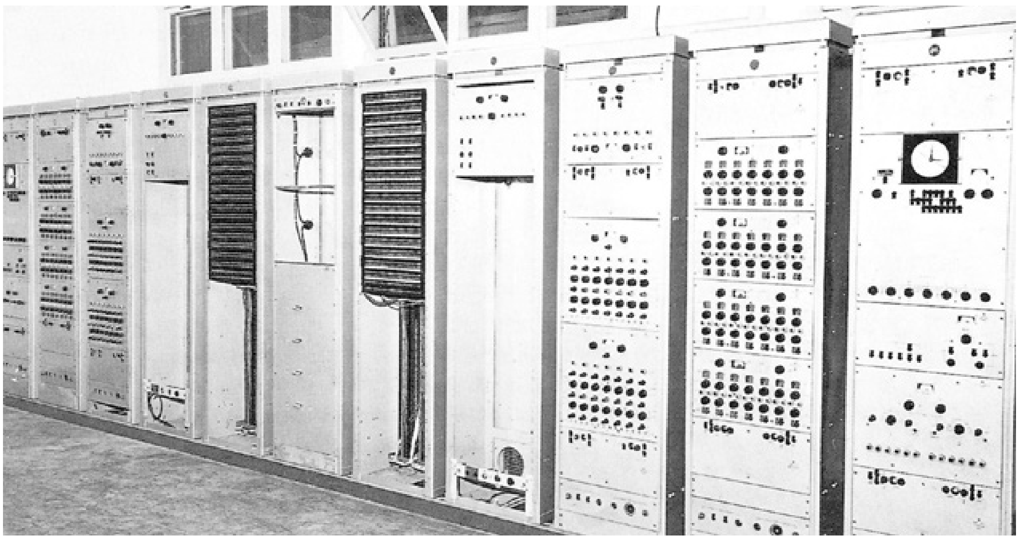
Bill Gibberd.

Soon after AWA took on the order for the two new Mk 2 CTUs, the British Ministry of Supply asked for two more to upgrade the timing facilities at the Aberporth range. At the time the flow of instrumentation development was overwhelmingly from Britain to Australia, but in the timing field Australia was already in the lead. Aberporth needed the equipment urgently, so it took the first two Mk 2s completed in 1951. The other two were delivered to Salisbury the following year after acceptance tests by LRWE at the AWA premises in Sydney.

A hard-working Electronics Group trio of Les Lock, Ken Lee and Ron Catmur—sometimes known not entirely flatteringly as Lock, Stock and Barrel—looked after the AWA equipment and developed the rest of the timing for the missile ranges until 1951. But in that year an ex-PMG telecommunications engineer, Bill Gibberd, took over LRWE's small Communications section and persuaded Boswell to let him assume responsibility



Les Lock (right) and Ken Lee setting up the AWA Central Timing Unit at Range E in 1950.



The Mk 2 AWA CTU during installation at Range G (1952). It was a dual unit.

R. J. (Bob) Dippy.

for timing. There was an affinity between timing and communications, in that both sent signals all around the Range and both shared and were the main users of the land-lines linking the instrumentation posts. Others soon joined Gibberd, including ex-PMG engineers such as Ron Knightley who took over the missile range timing. Jim Frost transferred there from Bomb Ballistics Group to carry on his previous development work for Range A, which culminated in the central timing equipment at CH, described in Chapter 10. This much bigger Communications section installed other instruments, but for timing and communications they had to develop and manufacture the equipment as well. The number of trials at the ranges was increasing rapidly, particularly at Range E, now emerging as the main range. To keep up, a new phase began when orderly engineering design, planning and implementation replaced the earlier more experimental approach, usually to tight schedules.

The first timing installation by Communications section was at Range G, where eleven racks of the Mk 2 AWA dual central timing unit in a new building had by early 1953 replaced the small and crowded van. But this new CTU installation had a short useful life. It came too late for the RTV1 trials that had been the mainstay of this range but had just transferred to Range E; and it was used only for HSAL and anti-aircraft trials which persisted until the end of the year, after which Range G fell into disuse and then closed.

By early 1954 the second Mk 2 CTU was in place in the new Instrumentation Building at the rangehead, replacing the Mk 1 version in the nearby Communications Building. Unlike the earlier Mk 1 installations, which were in man-high racks on plinths with interconnecting cables below, this CTU had been rebuilt into tall racks 2.6 metres high and was connected by neatly stacked cabling in overhead racking, very much in PMG style. Catmur, who had transferred to Woomera in mid-1952 to operate and maintain the timing at Range G and then Range E, recalls that he was at first more impressed by the awesome height of the racks than by any improvement in performance over the Range G version.

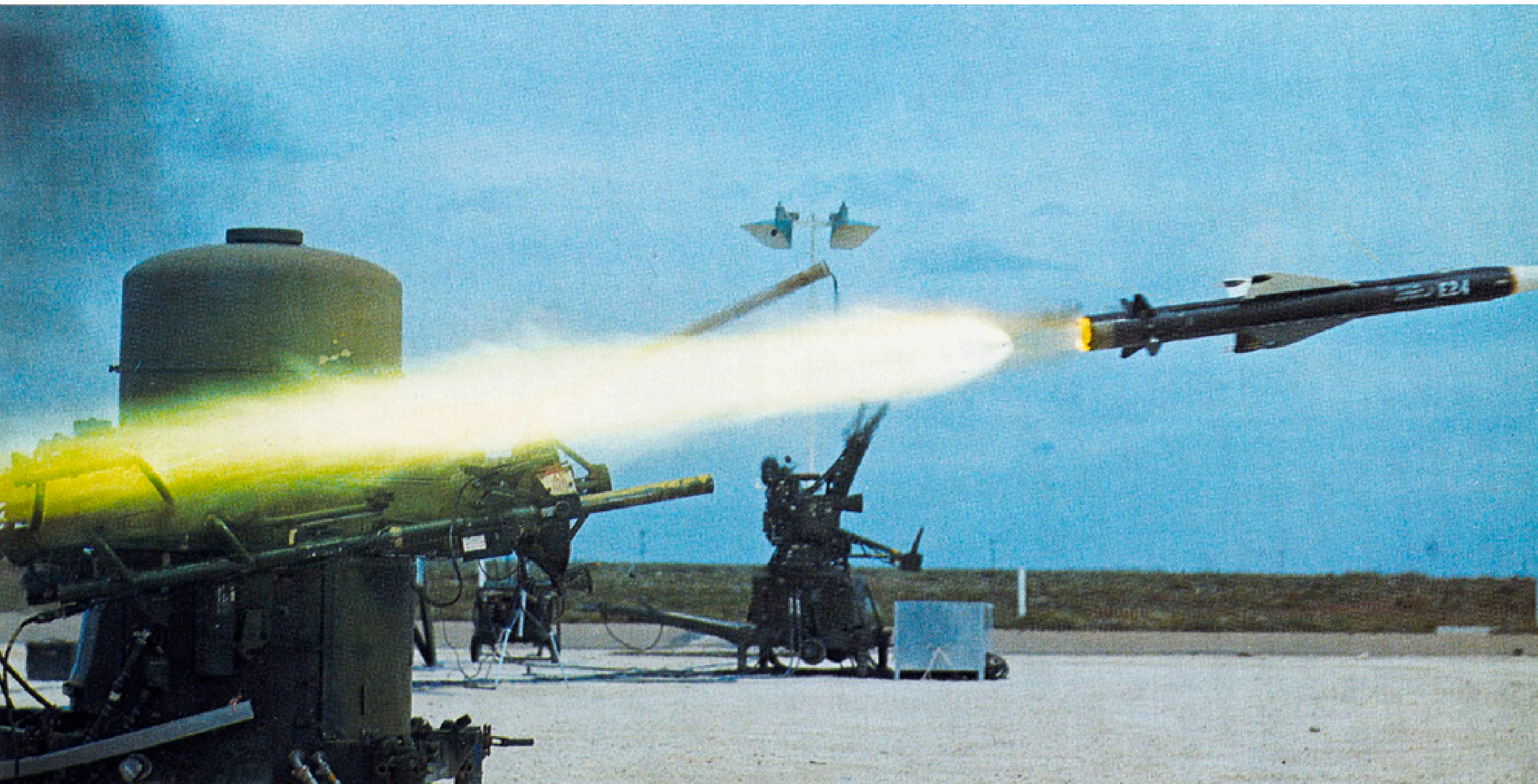
All the timing equipment mentioned so far generated uncoded signals. To correlate the timing on different records of the same trial, the data analysts at Salisbury had to count timing marks back to some common event marker, which in the early years was the 'instant of move' for missile trials. Most of the long records had some kind of ruler timescale to make counting easier (for instance 100, 10 and 1 per second marks), but even so it could be laborious—it was rather like measuring off distances on a long steel tape, which had regular divisions marked on it but no numbers given to the divisions. If the event marker was missing or there was a break in the record, reliable time readings might be impossible. To overcome this, by early 1953 George Barlow and his section in Electronics Group had developed a coded time generator, known as the Elapsed Time Code (ETC) unit and intended initially for timing Vinten cameras which were often required to start late in the trial, after the 'instant of move' marker.[2] It generated an output of 100 pulses a second (and was thus known later as ETC 100), binary coded to indicate the elapsed time since it was started, at one-second intervals. Communications section added a later transistorised version to the Range E CTU. The result was not entirely happy as the germanium transistors of the day were very temperature sensitive, and on hot days when the air-conditioning could not cope in the Instrumentation Building, the ETC generators failed.

By 1955 the first rapid growth in Range timing had run its course. Ranges E and A both had separate central units, each giving a comprehensive and acceptably accurate timing service. Both gave relative time and not time of day—they were electronic stopwatches, not clocks—but they catered for the needs of the relatively short trials being held at that time, so there was little pressure to develop them further. The instrumentation groups had already lost interest; while they all needed timing they were happy to leave it to the engineers in Communications, who had themselves moved on to developing intercom systems, sequencers and firing circuits for guided weapon trials.[3]

However, the calm was broken by a series of problems which persuaded the recently formed WRE Range Instrumentation Planning Committee to set up a special sub-committee on Range timing in July 1957. By then Range A had closed, but Range E was about to expand to its limit because of forthcoming Black Knight, Blue Steel and above all Blue Streak trials, so that timing signals would have to be transmitted by line or radio over very much longer distances with significant and uncertain time delays. Furthermore, ballistic cameras were now being used, and relative time was not enough; the cameras had to be star calibrated and so absolute time had to be known to calculate the accurate positions of reference stars.[4]

▲ A Bloodhound guided weapon emerges from the smoke of its four boost motors.

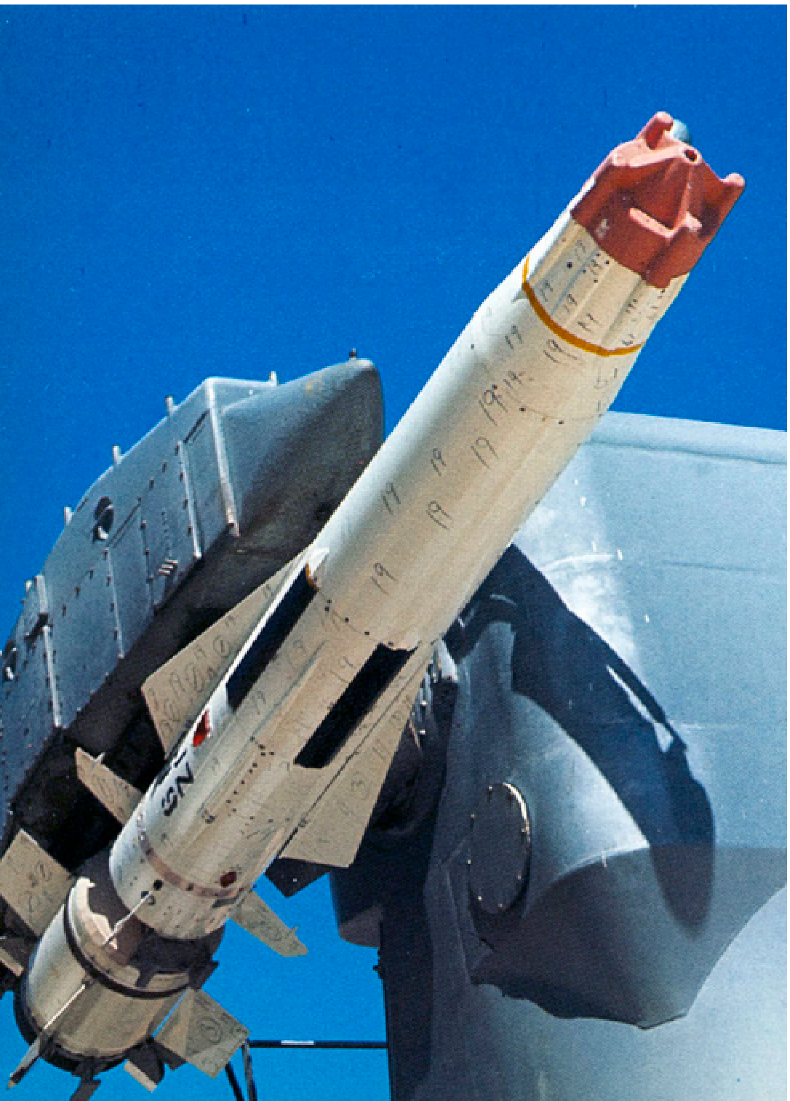
▼ A Blindfire Rapier launch at Area 5.



▲ The 10-metre-long launching tube of the Petrel supersonic rocket target, at its down-range site.

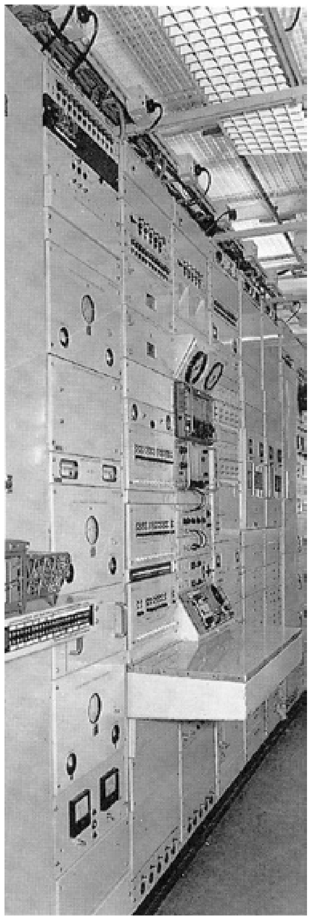
▼ Sea Dart awaits launch.

▼ The Australian Ikara missile is launched at sea.



So the sub-committee, with its rather grandiose title of The Universal Range Timing Sub-Committee, was set the tasks of recommending a suitable radio transmission system for timing signals where land-lines could not be used, and an absolute timing reference using coded signals.

No sooner had the sub-committee begun its work than problems arose in late 1957 when two Range users reported serious discrepancies when the time of the same event was measured by different instruments. For some reason these had not come to light before. These reports were neither tabled nor debated by the subcommittee, but they were discussed intensely in Radio Frequency Techniques Group, as Superintendent Emlyn Jones had channelled them to its newly recruited Principal Officer R. J. (Bob) Dippy, who had been one of the select group of scientists and engineers at TRE Malvern that developed Britain's pioneering wartime radar systems. Dippy's introduction to Range E in late 1957 was to investigate the discrepancies, assisted by Ian Macaulay. They found that serious discrepancies did occur, although not quite as large as had been claimed.[5] Dippy was soon given overall authority for timing in place of the sub-committee and he saw his first task as establishing a dedicated timing section in his group, renamed Electronic Techniques (ETQ) in 1958. He planned to reorganise the system by providing extra timing centres at Mirikata and Talgarno, with these two centres and Woomera all synchronised by radio signals issuing from a master station at Salisbury. This would be the time and frequency standard, keeping accurately in step with the international standard Universal Time (UT, the same as Greenwich Mean Time or GMT). The Range E CTU would be redesigned with greater accuracy and new time code generators would produce coded outputs, each giving an accurate read-out of UT clock time. ETC 100 could be scrapped once the new generators were installed.



Part of the Range Timing Centre at Range E after Dippy had reorganised the system.

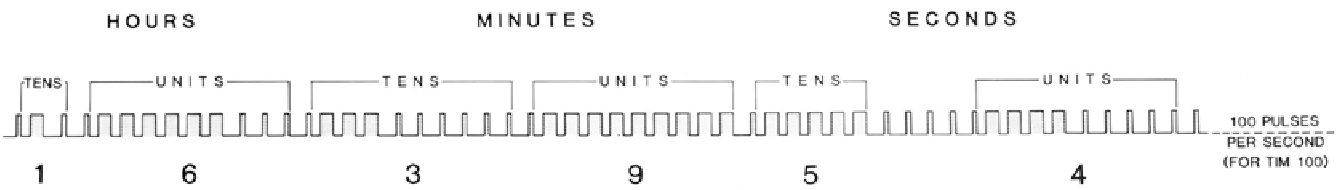
Apart from the Talgarno centre, which came to nothing, Dippy's ambitious scheme was mostly in existence by 1962. It was very accurate. The Salisbury station kept within 40 microseconds of UT by using very low frequency (VLF) radio transmissions from America and Britain that were controlled by atomic clocks. These clocks were a good deal more precise than relying on the rotation of the earth, which shows unpredictable irregularities.[6] The new basic oscillators at the Range E CTU, now known as the Range Timing Centre (RTC), were accurate to a millisecond per day, and they were constantly checked and synchronised with UT by sending radio timing signals to the Salisbury station for comparison with their standard.

Dippy had taken up the problem of timing errors caused by transmission delays, which were inevitable when sending timing signals from the RTC over long lines and through numerous amplifiers and equalisers to the instruments scattered across the Range. He suggested calibrating the network by radio, using a special LORAN transmitter (designed for a wartime navigation aid) working along a very stable and well-understood path of propagation. Thus was born the TIMAIR system, installed in 1963. Later a highly accurate battery-operated travelling clock was developed which did the same thing more easily, and TIMAIR fell into disuse by 1968.

The new time code generators gave four outputs known as TIM 1000, TIM 100, TIM 10 and TIM 1, in which timing pulses ranging from 1000 to 1 per second were coded in an easy to read format using narrow and wide pulses, so that the time (UT) and even the day in the year could be read at intervals. The choice of four codes allowed for different recording speeds. There were Tape Search Units that would automatically read time on a magnetic tape and stop the machine at a preset time reading.

Ron Catmur was introduced to the first coded service, TIM 100, soon after he took charge of the timing master station at Salisbury. Having survived the temperamental ETC 100 he was not amused to find his TIM display, an array of gaseous glow tubes, displaying an absurd time one morning. Despite being carefully reset, the display went adrift on several successive mornings. He got no sympathy from the designers who thought he was

Part of the TIM 100 coded time display, one of the four used at Woomera from about 1962. The others ranged from a slow (1 pulse/sec) TIM1 to a fast TIM 1000. The code was read simply by counting the long pulses in each group, here 16hr 39min 54sec Universal Time.



using it incorrectly; but, playing the detective, Catmur finally tracked down the cause. It was a cleaner who assiduously dusted the equipment every morning. She generated an electrostatic charge as she whisked her feather duster across the TIM display, enough to upset the sensitive glow tubes. A wire mesh screen soon put matters right.

With the satellite-launching programs of the 1960s the timing requirements moved far beyond the boundaries of the Range. As it happened, the need to calibrate ballistic cameras against the moving star background had fortuitously prepared the way, so that when the first satellite, WRESAT, went into orbit from Woomera in November 1967 Range timing was already synchronised with Universal Time and thus with the worldwide NASA tracking network.

SEQUENCERS AND HAZARDOUS CIRCUITS

'Sequencers' or 'program units' were digital counters used to switch equipment on and off automatically at preset times during the trials countdown. They also triggered the firing and other circuits in missiles. Early sequencers were rudimentary electromechanical stepping switches, but these were superseded over the years by more advanced designs using solid state electronics.

Woomera's first sequencer was the Master Control Box, developed at Orford- ness in 1947-48 for bomb ballistics trials at Range A and already mentioned in Chapter 10. it was made of electromechanical relays and 'uniselector' stepping switches, as used in the automatic telephone exchanges of the day. The first trials on Ranges F and G with the simplest unguided missiles were mostly switched by hand, but the much more complicated launching sequence of even the early guided rocket RTV1—with up to a hundred separate events to initiate—ruled out manual control. So the specification given to AWA in 1949 for the Mk 2 CTU was expanded to include a sequencer, which in effect would take over control of the trial up to firing time.

AWA completed the two sequencers by the end of 1952, but they were obsolete before either was fully installed. Late in 1953 Communications section started on a new design, replacing the noisy uniselectors with quieter and more efficient Ericsson crossbar switches, which the PMG later adopted for use in automatic telephone exchanges.[7] The new crossbar sequencer was installed next to the Range E CTU in 1954, and a similar one at Range A the same year. Each was driven at one second intervals by its CTU.

At Range E the sequencer could be used to control up to six minutes of the countdown, from minus 120 to plus 240 seconds (later extended to one hour to cover the big rocket launchings). Its main purpose was to control the many events that had to happen during the firing of a complex missile both before and after launch, including switching on and off certain instruments such as the unattended launcher cameras. It also gave out time pips and displayed sequence time at key operating positions. Yet the sequencer was no inexorable master of the trial. The trials control officer could stop or interrupt it at any time, and selected outposts could press a button to hold it when necessary.

By the early 1960s it was known as the Main Sequence Unit (MSU) as it had spawned sub-sequencers at some of the launchers which controlled local events. These were independent in the early stages of the countdown, but were locked to the MSU later on. Then in 1963 the original crossbar sequencer was replaced by a new version, using integrated circuitry for the first time. Crossbars were retained but to select the appropriate launcher and not to count as before.

Of the hundreds of MSU output circuits, many had very special treatment indeed as they controlled hazardous events such as arming and firing missiles and actuating the release jacks that allowed Black Knight and Europa to leave the ground. As Range authority, WRE was responsible for safety through its immediate representatives—the Range Control Officer in the Instrumentation Building and the Launcher Officer at the launcher. Each man had charge of a multiple switch intercepting all the hazardous circuits, so that the Range user could not fire the missile until both officers were satisfied that all was safe and had thrown their switches to 'arm'. Hazardous lines ran in separate protected cables and terminated in locked boxes, and there was an elaborate approval and inspection procedure for new designs and installations of hazardous circuits, no matter how simple they might be technically. Not all hazardous circuits were controlled by the MSU. Some were initiated manually and others by timing switches and other automatic devices in the missile. One used a special radio link—the command break-up system—described later.

The 1963 version of the MSU lasted until the last stages of the project, when Ranges Group replaced it with a simple Instrumentation Program Unit. As its name suggests it was intended only to control instrumentation, but this was modified later. The only hazardous circuits left at the Range were at the single launcher area kept operative after 1980 for the few and modest Australian rocket trials.

COMMUNICATIONS

'Communications' had many meanings at WRE. The term covered not only the extensive voice intercom system at Range E which kept everyone in touch with each other, but also the links (underground and overhead cable and radio) along which passed both voice traffic and instrumentation data. Line and radio communications extended well beyond the Range: there were telephone and teletype links to the village, to Salisbury and beyond; plus data links to Salisbury and a very widespread radio network. Until the reorganisation of 1968, all this was coordinated by Communications section and its successors.[8] This section provided most of the intercom systems, internal lines and the radio network, and it was also the point of liaison between WRE and the Postmaster General's Department (PMG), which provided and maintained the external lines and the telephone services—at joint project expense.

LINE COMMUNICATIONS AND TELEPHONES

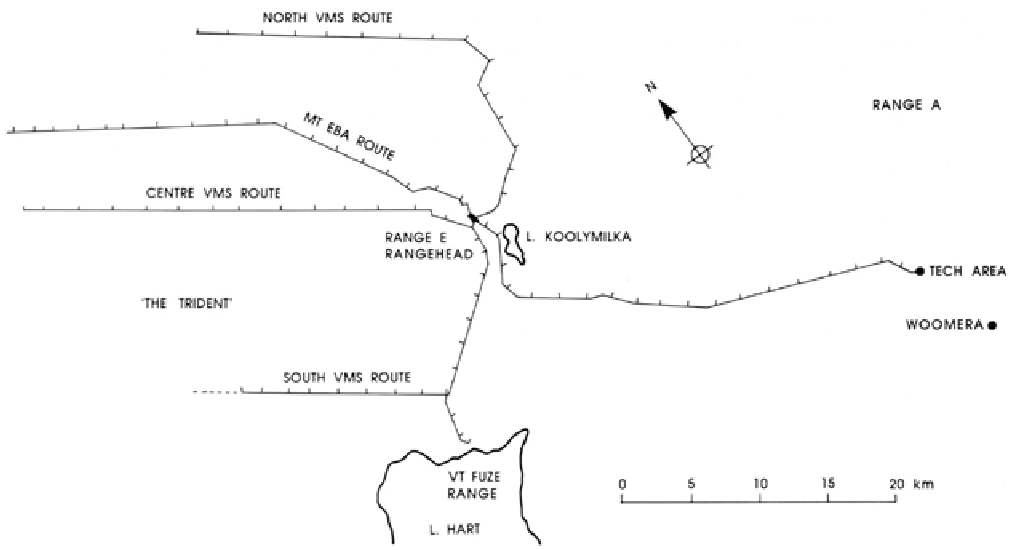
Major Morrie Bennett (right) with PMG Engineer Don Burnard.

Work began on line communications soon after the Woomera site was selected in early 1947. The immediate task was to link Salisbury with the temporary camps at Phillip Ponds and near the airfield site. Fortunately, nearby Pimba was already on the east-west telephone line, which ran along the transcontinental railway to link Adelaide with Perth. The PMG linesmen simply ran a short pole route from Pimba to a small shack on the site of the future Woomera Post Office, and from here temporary lines to the nearby Army and RAAF camps. But this was only the start. The bomb ballistics range was to be established in 1948, closely followed by the main range- head, and all needed good line communications.

At this early stage the PMG was only responsible for the external link to Woomera. The Department of Works was the authority for all construction work for the project and this included communications. Although it sought advice from the PMG at times, Works used the Army to build its lines. A unit of the Royal Australian Corps of Signals known as No. 1 Line Construction Project Squadron (1LCPS), under its colourful leader, Captain Morrie Bennett, had been despatched to Woomera in 1947. 1LCPS set up its own campsite, known as Bennett's Camp, at the new bomb ballistics range in 1948, and made a start in bringing a pole route from the Technical Area and in linking the instrumentation sites with underground cables. Bennett was soon joined by a group of 'Balt' migrants and an energetic Warrant Officer named Aub Reilly, who spent many years at Woomera including a long period as Works and Services officer in charge of the important Arboretum. Reilly was already known for his inventiveness, and he speeded up the process of laying cables in the stony gibber country of the bombing range by modifying a cable plough, by fitting a special shield to it to protect the cable from stones.

Aub Reilly (1962 photo).

Early in 1949 the PMG took over responsibility from Works for all internal telecommunications including line, carrier and ground radio systems. The move came from Works which had more than enough to do elsewhere at Woomera. The PMG itself was short of men and had an enormous wartime backlog of work; but it accepted the transfer provided the services of 1LCPS came with it, which was agreed. The PMG set up a special Long Range Weapons Project section in the Engineering Branch in Adelaide, and several men were given specific duties: Don Burnard (later assisted by Frank Gubbins) co-ordinated PMG work at Woomera, with Ted McGrath on radio and Bert Retallack on carrier systems. They worked with ex-PMG engineers Ted Marks and later Bill Gibberd of the WRE Communications section to decide on the network of communications needed at Salisbury, the village, the Technical Area and particularly at the several ranges then being planned. Another key figure was Frank O'Grady, then in charge of the PMG Transmission Laboratory in Adelaide and later Chief Engineer of LRWE until his return to the PMG in 1956, where he rose to become



One of the early open wire pole routes, built by Bennett's Army unit in 1950-51, was known as the 'trident': it ran from Technical Area to the main rangehead, and then branched into three prongs to serve the 'Velocity Measuring Set' (VMS) doppler equipment. The 130 kilometre route to Mt Eba was added in 1952, and was then intended to extend eventually 2000 kilometres to the Indian Ocean.

Director-General. After some fierce arguments, during which Evetts's peppery consultant engineer Wynne-Williams argued passionately against it, the principle was established that LRWE and the PMG in Adelaide should consult directly with each other over technicalities, with the Melbourne HQ being brought in only when financial approval for the work was sought.[9] Soon after this the Works part of the procedure was also decentralised, and from then on Melbourne HQ left all the details to be sorted out directly between Salisbury and the state branches of PMG and Works.

At a conference in January 1949 the PMG representatives were told that the network at the bomb ballistics range was almost finished, and the next project was to be one known as the 'trident'. An overhead 35 kilometre pole route was to run from the Technical Area to Lake Koolymilka near the rangehead. Here it would split three ways, with one route continuing 32 kilometres down the Range centre line, another turning right for 13 kilometres then hard left for another 19 kilometres, and the third following suit on the left hand side except for a short branch to the new VT Fuze range on the edge of Lake Hart. The three prongs of the trident were called the North, Centre and South VMS routes, and a corresponding trident of roads was to be graded, all intended to serve the British Velocity Measuring Sets then being developed for the RTV1 rocket.

1LCPS started on the trident soon after the conference, with PMG staff inspecting the work at intervals. After some months Reilly persuaded Bennett to shift from Range A, where large bombs would soon be falling close to his camp, to a new campsite on the shores of Lake Koolymilka, then drying out after its recent rare filling. Here Reilly erected an overhead track at the edge of the escarpment and started a production line to assemble the sectional steel poles, first dipping their ends in tar and then bumping them tightly together using a pile driver on its side. He also constructed an Australian Rules football oval with goal posts of the same sectional steel: this oval was obligatory as Bennett was a football enthusiast (Reilly claimed Bennett had deliberately recruited soldiers for his squadron who could play football). Years later these old goal posts remained as mute archaeological remnants of Bennett's vanished campsite.

The handle of the trident, joining Technical Area and Koolymilka, was finished by April 1950, but progress on its prongs was slower. By now the early RTV1 trials were being planned for a separate range, so the accent was now on Range G rather than Range E. It was not until August 1951 that the PMG considered the work complete, although the last three kilometres of the southern prong through difficult country was never attempted. By then VMS was fading away and the dopplers that succeeded it were elsewhere and connected by underground cable; the VMS routes were however used for other purposes.[10]

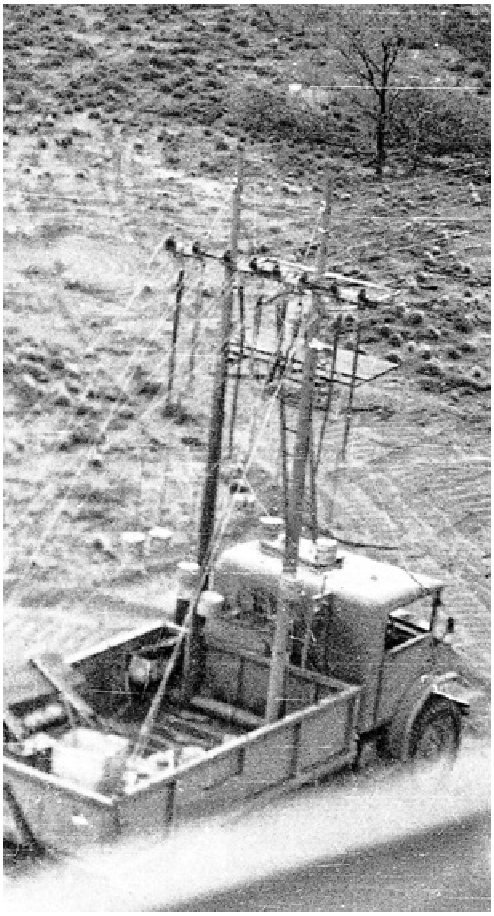
By 1951 attention had turned to a more ambitious line route, intended to extend eventually 2000 kilometres across the continent.

At the birth of the joint project in 1946 the main telecommunications challenge seemed to be linking together the string of observation posts (OPs), due to stretch across vast tracts of arid semi-desert between the rangehead and the Indian Ocean. Butement discussed this problem with others and produced a paper for the 'Bible'[11] which estimated that up to thirty speech and 119 instrumentation channels would be needed. The paper speculated on the possible choices: multicore buried cable with repeaters every 30 kilometres; overhead open lines with multichannel carrier systems and a 160 kilometre repeater spacing, coaxial cable, or a microwave radio relay. Even a carrier link superimposed on overhead power lines feeding the OPs was considered. The study had to be tentative, when so little was known of the climate, terrain or costs.[12] Soon after the Evetts eleven arrived in Australia early in 1947, the matter was taken up again with the PMG and Department of Works; while Boswell, himself an ex-PMG man, discussed the channel requirements with the relevant specialists.

Of Butement's options, open lines and radio now became the main contenders for the OP link. The PMG had already experimented with radio links, but had decided that no suitable equipment was yet available; in fact ten years passed before it started to use radio on trunk routes.[13] Traditional open wire lines had long been used successfully under arid desert conditions and would probably be cheaper to maintain than radio. In addition, Bennett's 1LCPS was already at Woomera. So the decision was made in 1950 to make a start on the line to the Indian Ocean by stringing four pairs of bare copper wires on poles between the rangehead and the site selected for the first OP, some 130 kilometres down-range. This was a recently abandoned civil airfield next to the Mt Eba homestead; the one used by the Evetts party on its first visit to the area in May 1946.

After a preliminary reconnaissance of the route, work started early in 1951 with a survey by Len Beadell of LRWE, who also pegged the exact positions of the first 634 of the 3345 poles to be erected, at the rate of about twenty-five to each kilometre, leaving the rest to the Survey section of the Department of the Interior. Beadell afterwards became famous for his undeviating 'gunbarrel' roads in more remote areas to the west, but over the Mt Eba route he was hampered by intervening salt lakes and the need to run parallel to the Range centre line before turning north to Mt Eba. Nevertheless, one utterly straight stretch of 60 kilometres did look quite impressive from the air.

1LCPS then erected the poles, cross-arms and insulators, and strung and tensioned the copper wires, all within the year. The resourceful Aub Reilly claimed that he met the schedule thanks only to several inventions that he devised in the field. The most ambitious



Far left: Len Beadell surveying.

Left: Tensioning wires on the Mt Eba route with Aub Reilly's 'Colossus'. This is the only photograph available.

of these was the Colossus, which speeded up the process of tensioning the wires strung between the poles. The traditional method was to fit special stays to a pole at intervals and fit the cross-arm with pulley wheels so that weights could be hung on the wire to tension each length in turn. Reilly's invention sat on the back of a truck, which was driven under the pole and tensioned the wire from the platform. The PMG later adopted a more sophisticated version of Colossus for general use.[14]

By July 1952 the line was through to Mt Eba and approved by the PMG for the three and twelve channel carrier systems for which it was intended. But some years passed before it came into full use, because Mt Eba was not used as an instrumentation site until 1957 when an MTS station (P6) was established there, followed by telemetry, radar and other equipment. To provide them with intercom, timing and other services a PMG twelve channel carrier system was installed, using one pair of wires. By 1960 the route had been extended a further 53 kilometres to Mirikata, home of the advanced radar for Blue Streak and Blue Steel. Other lines connected Mirikata with Hawks Nest and McDouall Peak instrumentation sites, both used for Blue Steel.

Mirikata turned out to be the limit of the string of trans-Australian OPs as originally conceived by the Range planners. WRE's line communications did indeed almost span the continent when they were extended to Talgarno in readiness for Blue Streak. But by this time the PMG favoured a much longer and indirect route, running from the rangehead to Pimba, along the east-west route almost to Perth and then north.[15] Nearly all the new work was in Western Australia, including the upgrading of an existing route from Mullewa to Meekatharra and erecting a new trunk line 800 kilometres north via Marble Bar and Port Hedland to Talgarno. After Blue Streak the PMG took it over and later extended it into the Kimberleys, which gave the remote settlements and mines in this north-west corner of Australia a first class telephone link to the rest of the continent.[16]

While overhead wires and carrier systems were favoured for the longer routes, underground cables linked all the elaborate instrumentation over the first 30 kilometres of Range E. The cables contained many pairs of twisted paper insulated copper wires in a lead or plastic sheath, and on some links such as that from the rangehead to Launchers 5 and 6 many hundreds of pairs were provided.

1LCPS had left in 1952 after finishing the Mt Eba line, although an army line maintenance unit stayed on for a while. After it too left, the PMG handled all the laying and maintenance. Communications section wired all the buildings internally except for the telephone services. There was a line of demarcation in each building—a Main Distribution Frame where both parties terminated their cables. And the PMG had their own Communications Building near the Instrumentation Building, where most of their cables terminated and which housed their carrier and telephone equipment. There were however few demarcation disputes between the PMG engineers and those of Communications, many of whom were ex-PMG anyway. The former's maintenance men were very good at finding and fixing cable faults quickly, so avoiding expensive trials delays.

The PMG also provided the telephone service at Woomera and the Range (at joint project expense) and at Salisbury. By 1956 most centres had automatic systems, including 300-line private automatic exchanges (PABX) at both the Technical Area and Range E, but Woomera village had a manual switchboard for many years more. Four telephone and three teletype channels rented from the PMG linked Salisbury and Woomera, and there were thirty-six telephone channels between the Technical Area and Range E. None of the internal or external telephone lines was secure, and classified matters could not be discussed over them. Later, people were also warned not to speak about classified subjects even close to telephones as the receivers could sometimes transmit speech even while on the hook. The teletype links between Woomera and Salisbury and secure terminals in Melbourne, Canberra, London and elsewhere passed encrypted messages.

As the project passed its peak of activity in the later 1960s, so did the line communications and telephone system shrink in sympathy back towards the range- head. By the end the PMG had either taken over, salvaged or abandoned everything except the much smaller network preserved for future trials on the remnant Range E. There were a few lasting benefits: the Woomera–Mt Eba–McDouall Peak-Ingomar route was extended to the remote opal mining settlement of Coober Pedy.

INTERCOM

While ordinary telephones were quite suitable for homestead warning, they were never used for communication between staff during trials. Elaborate intercom networks were used instead.

An early intercom system was installed on Range A in late 1949 and then on Range G, using commercial Philips Philiphone units. These were simple audio amplifiers with speakers and switching, and to reply to calls one had to operate a press- to-talk switch and use the speaker as a microphone. The Philiphones were made for offices, and when connected through the underground cables used at Range A they were very prone to cross-talk—not only could one often hear conversations intended for other posts but timing signals as well. To overcome this, balancing line transformers were incorporated in the Model A intercom sets installed later at Range G and Range E. These were made to an LRWE specification by STC Sydney.

Both these early intercom sets used a pair of wires, which were switched from input to output when the 'press-to-talk' was operated. One problem was that the volume control had to be adjusted constantly to cope with both faint distant and deafening close stations. To overcome this Bill Gibberd of Communications drew on his PMG transmission experience and pioneered the use of four-wire intercom, in which separate receive and send line pairs were used with a central amplifier. With this arrangement different line losses could be easily compensated.

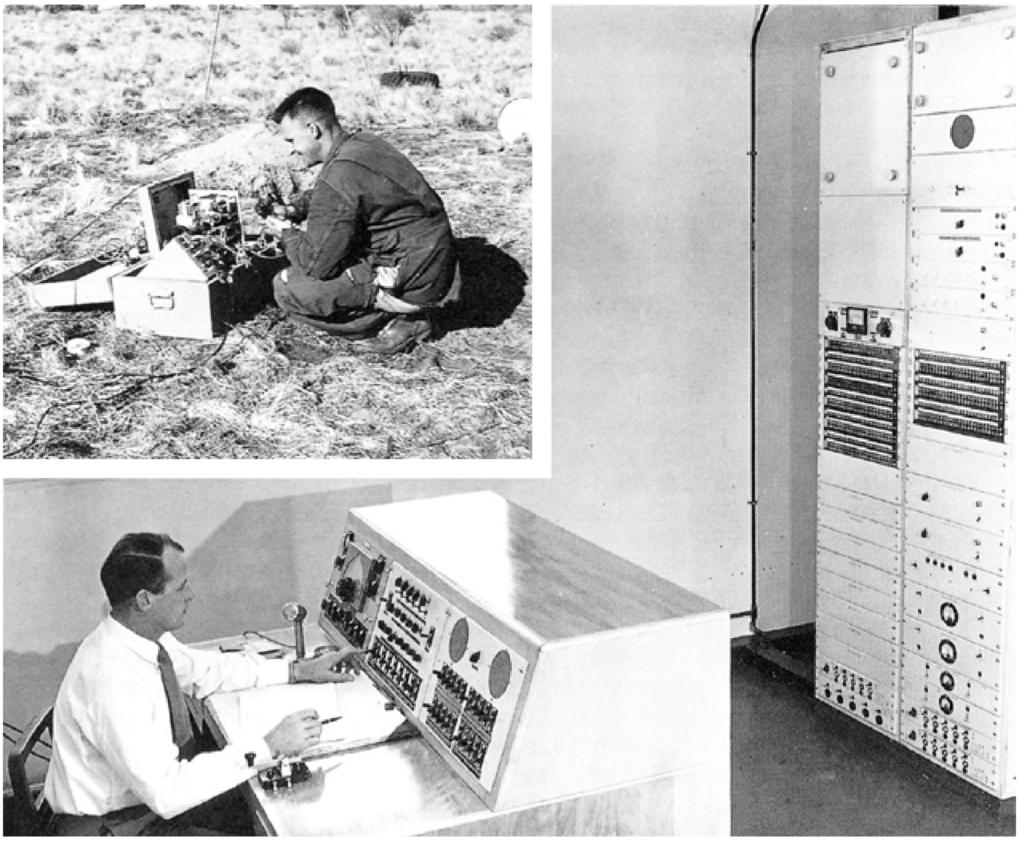
LRWE developed and manufactured new four-wire intercom equipment, and it was installed on Ranges A and A1 by late 1953 and in the new Instrumentation Building at Range E the following year. Even in these early years there were many stations, and they were arranged in twelve separate nets so that all stations that needed to could hear each other but would not be distracted by conversations on other nets. There were also mixing and splitting facilities so that trials control staff could switch to any net or broadcast trials briefings and countdowns on all of them.

As Range E developed in the following decade its intercom system grew steadily. The twelve nets of 1954 became forty in 1959 and more were added later to serve new facilities at Area 6 for ELDO and elsewhere. The system was even more extensive than timing, reaching to the furthest corner of the Range, and during the years of growth services were continually expanded and the sets improved; there were for example over 250 new services in the twelve months from July 1961. But by the late 1960s the growth had virtually ceased, and in the run-down period after 1976 the system shrank back to twelve nets, with sets left in only the few retained posts.

RADIO COMMUNICATIONS

We have already noted that in the beginning line transmission was chosen over radio for the instrumentation and intercom signals. Lines were simpler, more reliable and more secure, and these advantages outweighed the cost of lines and the fact that once laid they cannot easily be moved. Later on radio sets became much more compact and reliable, and this shifted the balance back in their favour; but by then expansion had ended and the existing lines could cope with the short range trials of the day if augmented at times by temporary field cable.

Radio was of course indispensable for conveying information between airborne objects and the ground, or between moving objects on the ground, and there were many such radio links apart from telemetry and the radio tracking systems already discussed. Thus VHF radio was used to communicate with manned aircraft used in bombing and air-launched weapon trials, and there were others such as the target aircraft radio control link and WREBUS for the destruction of missiles. The most widespread was the HF radio network which communicated between mobile and fixed stations. The main base station was in the Technical Area at Woomera, but a Salisbury station (VL5BV) was sometimes used as a base. There were more remote fixed stations at Giles, Maralinga and for a time at distant Talgarno, which could communicate with mobile stations in the vicinity or with each other (via Giles or Maralinga in the case of Talgarno). The NPO, survey, reconnaissance and some Works vehicles had mobile transceivers working on a common General Range Net (VL5BW). Over 70 vehicles had been fitted with HF transceivers by 1967. The units used in the 1950s were



The Woomera Communications Centre (1957). *Inset*: Repairing a Peppercorn mobile HF transceiver in the field.

known as Peppercorn sets, not because they were small (they were not) but because Ted Peppercorn of Electronics Group had designed them. They used valves, of course, and tended to flatten the battery, so they were replaced later by ones using germanium transistors with more modest power requirements, designed by Lloyd Butler of Communications section.

The Technical Area station was established in the early 1950s in the Filter Room of the Admin Block but was moved to the nearby Range HQ building in 1954. It was upgraded from time to time, and in 1957 became the Woomera Communications Centre. During the busy years following, the Centre was manned continuously by three operators working in shifts from 4 a.m. to 1 p.m. daily, whose job was to maintain radio watch on the five HF frequencies available. The transmitters were in a nearby separate building with adjacent aerial towers, but the receivers were some distance away in what had originally been Range G. Not long before the end of the project this HF system was re-equipped by replacing the transmitters by more efficient single sideband sets.

A separate HF net (VL5BU) was used by the fleet of recovery vehicles on Range E, with a rangehead base station which could also use the General Range Net.

COMMAND BREAK-UP

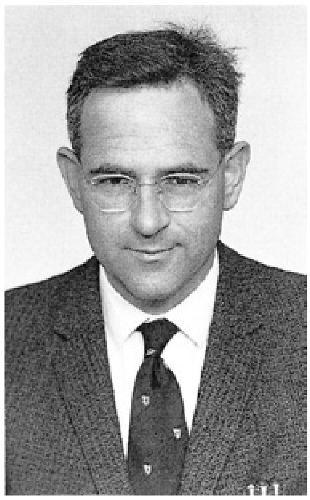
One particular radio link was given very special treatment. This was the Command Break-Up system, which existed solely to send a signal to an errant missile to trigger its self-destruct mechanism. Command Break-Up was an integral part of the flight safety tracking chain which, as we have seen in the previous chapter, received considerable attention from the WRE instrumentation and safety people during the period of rapid Range growth from the mid-1950s to the early 1960s. Compared to the other items in the safety tracking chain the system was simple enough—all it had to do was relay yes-no commands in one direction—but it had to do so with utter reliability.[17]

In the early days there was little danger of impacts outside the trials area, for the weaponry under test was either bombs or short range missiles, neither of which were likely to transgress the generous Range boundaries. The RTV1 test vehicles were sometimes fitted with clock devices like time delay fuzes to explode small break-up charges, which also helped reduce the area which had to be searched during recovery. Similar clock devices were used from time to time in later missiles, sometimes to support the command systems, and there were other types of automatic break-up as well. One example was the accelerometer system fitted to Europa I which triggered all residual explosive devices when it sensed re-entry to the atmosphere.

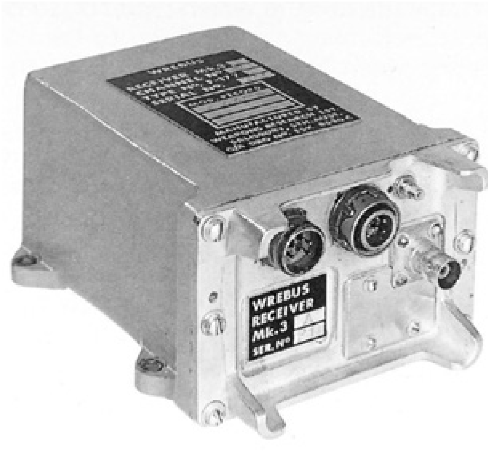
The need for command break-up first arose in 1954 with the advent of the guided weapon trials. Guidance trials of Red Shoes, Red Duster and Seaslug were expected to start in 1955. It had to be assumed that the missiles would sometimes misbehave and head at full power towards a Range boundary, and the clock type of break-up system might not work in time. Now Aberporth already had a radio command device, called the Doppler Trigger Unit (DTU) because it used the doppler transmitter on the Range to send a coded 'destruct' signal to the missile. The DTU had been tricky to develop, and was never entirely reliable.[18] But WRE had to use it in 1955 because it was available and the trials were imminent. Range E had no problems adopting the DTU. It already had a doppler system like the one at Aberporth which could be fitted with the necessary coders, and the missiles would be coming to Australia already fitted with DTU devices in their doppler transponders. So the decision was taken to use the DTU temporarily at Woomera. About the same time a specification was drafted at Salisbury in December 1954 for an improved system to overcome an inherent weakness of the DTU: the fact that it worked on the fail-inert principle. That is, it worked only when the break-up signal arrived, and if the signal did not get through (if radio contact was lost, for instance) then the misbehaving missile would fly on heedlessly. For these early experimental missiles a more rigorous fail-destruct mode was much to be preferred. One way of managing this was to send a coded signal to keep the system inhibited during normal flight, and then switch it off to cause destruction. An accidental loss of signal would then also cause destruction. The fail-inert mode as used in the DTU system might be satisfactory later on for proven missiles, and it would of course be much more popular with Range users anxious not to have their perfectly good missiles cut down because of a transmission failure, particularly if they wanted to recover the missile fairly intact. So the specification called for either mode to be selectable as required.[19]

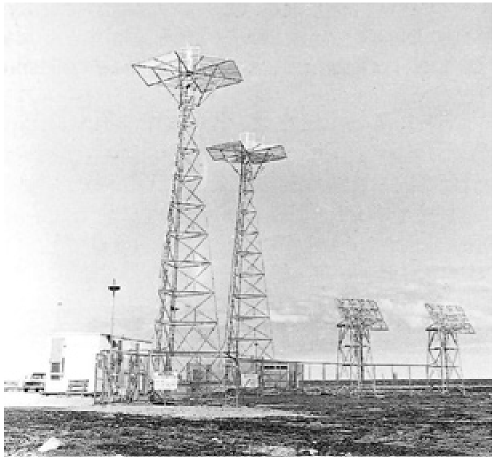
Not unexpectedly, Woomera's experience with the DTU in the 1955 trials was no better than Aberporth's. Reliability was only about 75 per cent, which was unacceptable for a safety device.[20] WRE's Safety Officer was put in the awkward position of having to grant dispensations to contractors to omit the DTU, which sometimes acted unpredictably in a fail-destruct mode and destroyed valuable missiles.[21] It is not surprising that in August 1956 it was decided to develop the WRE system that had first been specified in December 1954. Shortly afterwards it was given the name WREBUS (WRE Break-Up System) and demanding new requirements added. WREBUS had to be highly reliable, respond rapidly, be unaffected by radio interference, and have small airborne elements. Also it had to be quite independent of other tracking equipment. The DTU used the doppler radio link to the missile, which relied on a tracking aerial slaved to a radar or optical tracker. The link was liable to fail at the critical moment, because it was very easy to lose track of a misbehaving missile.

Dr Dick Trenam of El Group oversaw the development of WREBUS, and later became its System Authority. By May 1958 WREBUS had advanced enough to be tested very thoroughly in a series of sixteen special aircraft and missile trials over the following year. In 1960 it was ready for use in trials, although work continued on a number of improvements. The DTU system was retained for the time being. Further work on it since its first installation in 1955 had made it much more reliable.[22] But it still suffered from its inherent disadvantages of being fail-inert only and dependent on other systems. In 1962 WREBUS became the standard at Woomera, although DTU was retained for a few years longer as a precautionary back-up. By then long range trials of second generation guided weapons were in progress and needed the better performance of WREBUS. Further, a survey of some seventy trials showed that WREBUS ground and missile equipment had behaved perfectly (the four failures had external causes such as loose connectors in the missile circuits, and WREBUS had not been at fault). The British also decided in 1962 to make WREBUS standard on its RAE ranges, so the same receivers could be fitted to missiles whether they were due to be fired at Aberporth or Woomera.


Dr Dick Trenam.

There were two WREBUS ground stations on Range E; one near Lake Hart and the other at Red Lake. Each could send out up to three different 'fire' signals, allowing that many missiles or targets to be destroyed individually. To safeguard against accidental action, a 'prohibit' signal was sent constantly which positively inhibited the WREBUS receiver from





Right: A WREBUS receiver, fitted in hazardous missiles to break them up on radio command.

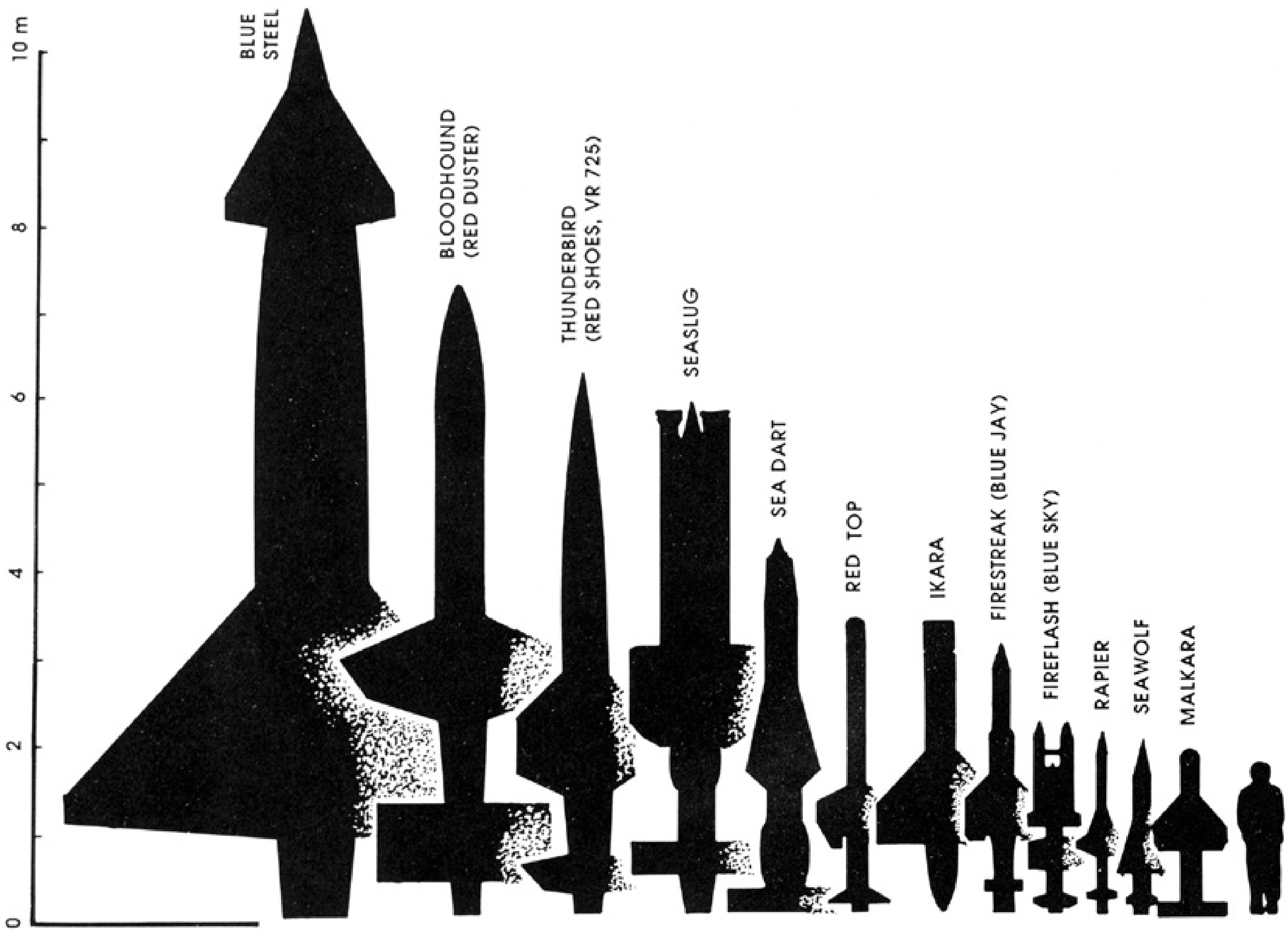
Far right: The WREBUS ground station S7.

operating the output relay. To cause destruction in WREBUS' fail-inert mode, the 'prohibit' signal was switched off and the correct 'fire' signal substituted. This operated a relay which set off the break-up charges in the missile. In the fail-destruct mode the action was the same except there was no need for a 'fire' signal: once the 'prohibit' signal ceased to arrive the receiver relay switched by itself after a short pause.[23] All the WREBUS equipment was removed with the run-down, for none of the trials since have been big enough to need any command break-up system.

Notes and Sources

1. Boswell's approach differed from that initially taken for the bomb ballistics range, where all instruments recorded their operating times on a central chronograph at post CH. For missile ranges the emphasis was on a central timing source and local time recording. By the mid-50s the two approaches had converged: both had central timing and chronographs as well, as the teledeltos type developed for Range A was also adopted for Range E.
2. LRWE Progress Report January-March 1953. P. O. Gillard claimed in 1981 that ETC arose from his request to Barlow for coded timing on his lengthy 35 millimetre telemetry 'histogram' records.
3. The account of events in timing from 1955 onwards is based on a contribution received in July 1983 from L. L. Anderson, who succeeded P. Rohan as System Authority for timing, and on WRE Progress Reports issued every six months between 1958 and 1962.
4. At first radio broadcasts of timing signals from the US stations WWV and WWVH were used but reception was often poor and propagation delays uncertain.
5. R. J. Dippy & I. J, Macaulay, 'An investigation into the accuracy of the AMPOR system timing used in target aircraft at Range E Woomera'. WRE Technical Note TQD18 (November 1958). See also WRE Progress Report January-June 1958, p.47. It is interesting to note that the latter comprises the first mention of work on timing in these WRE Progress Reports. The first six issues for 1955, 1956 and 1957 ignored it, although they devote many pages to other instrumentation systems, and the preceding LRWE issues had included brief reports on progress with the AWA CTU equipment. Subsequent issues reported increasingly on timing, culminating in almost three pages on it in the Report of January-June 1962.
6. The later ELDO tracking station at Gove used VLF transmissions to synchronise its own independent timing service to UT.
7. The first crossbar sequencer for Range E was developed around 1954. The PMG established its first main crossbar exchange in 1960 at Toowoomba, Queensland. See Ann Moyal, *Clear across Australia*, Nelson, Melbourne, 1984, p.227.
8. Communications section was not responsible for the radio telemetry link or the radio tracking systems.
9. Notes on a conference held 20 January 1949, File SA5043 part 4, folio 591C.
10. The North VMS route was extended in 1953 towards Parakylia homestead to serve the MTS sites P2 and P4, with a carrier system installed. By 1962 the central route had been extended to a point 65 kilometres down-range and a carrier system installed to serve the two new Contraves sites K27-K29 and K28-K30. The Southern prong of the trident was used only as part of a homestead warning link to Wirraminna, and later to connect a WREBUS site.
11. LRWO(A), 'Specifications for construction of projectile range'. General Appendix No 2. DRCS library ref. 623.591 (94) MS.

12. Minute from Acting Chief Superintendent LRWE to Controller LRW in Melbourne. See also undated paper 'A report on the communication plan for Range E'. File SA5043 part 4, folios 650Q and 660T.
13. The first PMG microwave radio link was installed between Melbourne and Bendigo late in 1959. The first interstate coaxial cable link from Melbourne to Sydney was opened in 1962. Moyal, pp.219-20.
14. From a tape recorded contribution by A. W. Reilly received in 1985. F. S. W. Gubbins, a retired Telecom engineer involved with the Mt Eba line at the time, afterwards paid tribute to the mobile line tensioning array and confirmed that the idea was afterwards successfully adopted by PMG.
15. The east-west route was upgraded in 1955-56 as far as Maralinga for the British nuclear weapon tests and this was extended to Kalgoorlie by September 1958. By 1959 trunk routes in WA extended north to Carnarvon and inland to Meekatharra. Moyal, p.214.
16. Moyal, p.216.
17. This section on Command Break-Up is indebted to contributions by the late Lt Col E. G. Foreshew, formerly Principal Safety Officer of WRE, and R. J. Moberly.
18. Minute dated 12 October 1954 from PO Missile Projects J. D. Heinrich. File SA5277, folio 44A.
19. 'Specification of requirements for Range 'E' Command Break-Up facility'. Second draft dated 16 December 1954. File S5573/8/3, folio 1A.
20. Notes attached to Minute from PO Missile Projects Group. File SA5277, folio 75A.
21. Letter from Project Officer to Bristol Aeroplane Company at Salisbury. File SA5277, folio 117.
22. Minute PO Electronic Instrumentation to Safety Officer. File S5573/8/3 folio 4. In the early 1960s the DTU system was upgraded further, including a higher power transmitter.
23. 'A handbook of instrumentation at the Woomera range'. WRE Manual 343 (3 July 1969). The WREBUS ground stations had special omni-directional transmitting aerials that gave effective coverage over a wide arc to nearly 400 kilometres down-range. There were also narrow arc aerials useful to nearly 1000 kilometres for the very long range trials.



Silhouettes of the major guided weapons tested at Woomera. All were British except Malkara and Ikara, which were Australian.

17 The guided weapons

INTRODUCTION

As we have seen earlier in some detail, Woomera was founded to prepare and test long distance bombardment weapons; and yet it came about that all the early military work at Salisbury and Woomera was in developing and testing relatively small guided missiles. For most of the life of the joint project the trials of such weapons were the bread and butter work of the Range, and they made up a large part of the work at Salisbury too. Even the advent of the larger space rockets, beginning with Black Knight in 1958, caused little interruption to the defensive weapon trials, and when space activities ended with Black Arrow in 1971 the second generation of guided missiles continued to occupy the Range well into the 1970s.

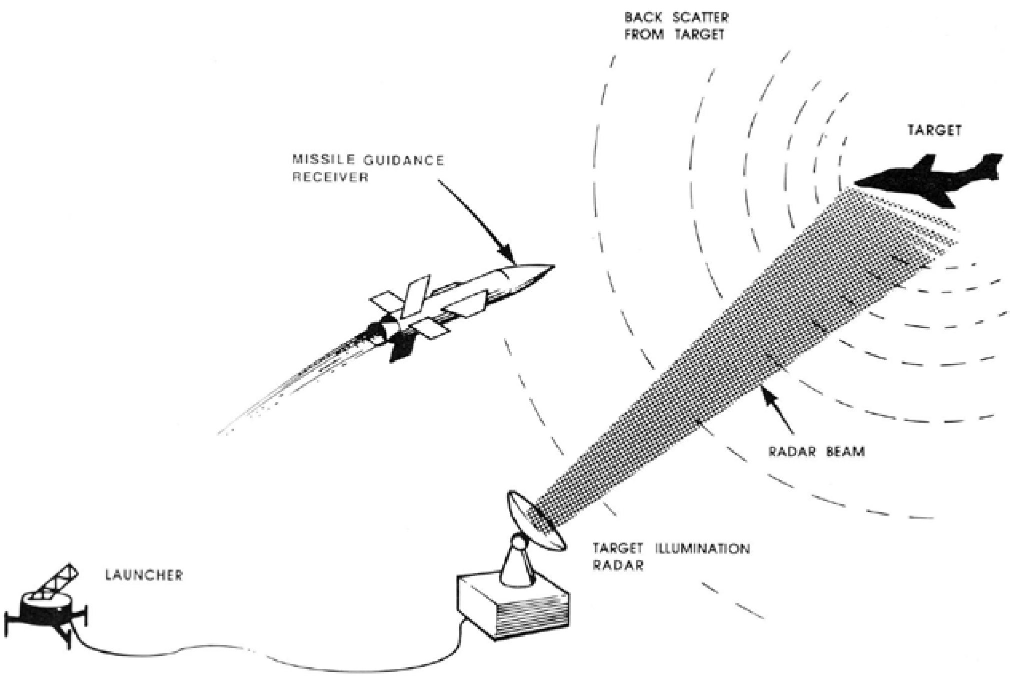
Over its 25 years of continuous trials activity Woomera saw a bewildering range of guided weaponry. Even if one restricts the count to only those projects which started out as a firm intention to produce a new weapon for the armed forces, the total is close to twenty. The trials program of each one lasted, of course, a very variable length of time. Some projects had a brief surge of trials, only to be cut short by a sudden cancellation when the operational requirement behind them altered or vanished. Others persisted for years, passing through a long evolution of test vehicles, type numbers and production phases, their early versions even reaching active service with the armed forces and then quickly being superseded by improved versions. However, each project added a quota of experience to its successors, and trials procedures became increasingly refined as time went by.

THE GENERA OF THE GUIDED WEAPONS

There are four obvious categories of guided missiles, all of which had their representatives at Woomera. First is the ground-to-air missile, designed to replace the anti-aircraft gun in defence against fast high-flying (and sometimes very low-flying) aircraft. Secondly, air-to-air: an airborne guided weapon enormously increases the destructive firepower of aircraft in combat. Next there is the air-to-ground missile, distinguished from the guided bomb in that it can fly to its target under its own propulsion after leaving the carrier aircraft. And finally there is the ground-to-ground rocket, ranging from a large artillery weapon for tactical bombardment in battle zones (or from ship- to-ship at sea) to a lightweight strike weapon for infantry use. We shall see shortly how these diverse types were represented in projects at the Range, and how certain variants emerged to fulfil very specialised purposes.

Guided weapons can be tailored to suit many applications but they all have their similarities. They are almost always a traditional rocket shape, with a slim streamlined body, stubby wings for aerodynamic stability, and a set of movable fins or (rarely) movable rocket jets to steer with. Typically the propulsive unit consists of a boost motor or assembly of motors which supply the initial acceleration before being discarded, leaving the missile to fly on by means of a sustainer motor or even as an unpowered coasting dart. Solid propellants are usual because of their instant readiness, although the sustainer is sometimes a ram jet burning kerosene in air or occasionally a true rocket burning liquid fuel in an oxidant.

A missile can be guided in various ways. The simplest is to let an operator direct it on to the target visually, passing commands over a radio link or even down a rapidly uncoiling strand of wire.[1] Alternatively, a narrow radar beam can be transmitted from the ground or a launcher aircraft. Once the radar is tracking the target, the missile can be made to 'ride the beam' to its objective. A more sophisticated method is to track by radar but to give the



Semi-active homing, as used for Bloodhound, Thunderbird and Sea Dart.

missile the means of receiving and following the radar echoes reflected from the target. This is called 'semi-active homing'. A further stage is 'active homing', in which the missile carries its own complete radar set and follows its own reflected signals to the target. Some guidance systems dispense with radar altogether, except to determine the general direction in which to launch the missile. Some 'fire and forget' missiles can detect infra-red radiation and guide themselves to its source—the hot jet pipe of an aircraft, for example. Nearly all air-to-air missiles use some sort of on-board homing. The weakness of all homing devices is that by their nature they can be disrupted or confounded. Systems of inertial navigation, generally used only in large missiles against fixed targets, avoid this weakness. They can be set beforehand for a destination and then sealed against the outside world, making them immune to all but direct attack. The art of guidance is in fact a continual process of one-upmanship: one develops a superior system to cure a weakness or limitation, only to have one's countermeasures followed by counter-countermeasures.

Whatever the method of guidance, the missile is steered by passing amplified signals to the actuators of the control surfaces. The actuators can be moved by pneumatic or hydraulic means, and the electrical power for the missile produced by batteries or some form of gas generator. The whole control system has to be carefully designed to suit the aerodynamic response of the missile, which must always be stable in flight with no oscillation or undesirable motion.

The flight path of the missile as it homes towards the target is controlled by shaping circuits which are very important in setting its trajectory. The simplest kind of trajectory is a 'pursuit-homing' one, where the missile flies after the target like a dog chasing a rabbit. Just as the dog wastes a lot of energy in following all the twists and turns of his quarry, so too can a missile be exhausted before it reaches its target, especially if the latter is on a crossing track. It is far better to aim, as a rifleman does, at the point where the target is calculated to be when the missile arrives. Most of the second generation missiles use this kind of 'proportional navigation'.

This leaves only the lethal component of the guided missile: the explosive warhead. Here again the design is adaptable to the purpose. Anti-aircraft missiles may use a fragmentation head, which is a type of grenade discharging a shaped pattern of metal projectiles. Alternatively, the head may contain a package of linked metal rods which open out explosively into a flying hoop of steel capable of severing the wing of an aircraft. In either case the warhead is usually triggered by a proximity fuze to make even a near miss destructive. In the later stages of project trials at Woomera armed missiles were used against target aircraft, but for much of the time the warhead was omitted and the space used for telemetry equipment.

NAMES AND NUMBERS

Each guided weapon project at Woomera had its own distinctive title, which was usually the name given to the missile itself. For security reasons the title was entirely arbitrary. Sometimes it was a mere grouping of letters and digits, but more commonly it was two words of which the first was traditionally a colour. (The few indigenously Australian projects were usually given Aboriginal names, such as the anti-tank weapon, Malkara.) Later on, and particularly when the weapon came into service, the code-name was replaced by something more distinctive and memorable: thus, Red Duster became Bloodhound. That might not be the end of the story, though, because when the more successful projects passed through their phases of redevelopment and improvement they were often renamed. Perhaps the most noteworthy in this respect was the first anti-aircraft weapon for the Army, which was successively named Red Shoes, Thunderbird, Green Flax, Yellow Temple and VR725, plus several intermediate stages and mark numbers. For some reason projects for the Navy were treated differently. The Navy's Seaslug, Sea Dart and so on bore a similar name from early development to operational service.

Finally, to bring total confusion to the uninitiated (which was perhaps the intention) the two-part development names were used for entities other than missiles. The radar set used in conjunction with Bloodhound and Thunderbird missiles bore the gloriously surreal name of Indigo Corkscrew.

THE FIRST PROJECTS

In 1947 three different types of guided weapon were being considered for development to meet the demands of the British armed services.[2] Foremost was a ground- to-air missile, initially called Red Heathen, which was required by both the Army and the Air Staffs for defence against aircraft, particularly against high altitude jet bombers with the predicted performance of ten years hence. The weapon was to have 'medium' range, meaning that it had to intercept targets up to 45 kilometres away and at altitudes of up to 60 000 feet. Secondly, the Royal Navy wanted its own version of such a missile to protect its ships against attacking aircraft; in this case the range could be somewhat less, but Seaslug (the name given to it) had to be capable of being stowed on board and launched at sea. Thirdly, for air-to-air use, both the naval and air staffs jointly specified a new airborne guided weapon. Red Hawk, as it was called, was originally conceived as a beam-riding missile directed by the launching aircraft's radar. It would attack at relatively short range with a flight duration of about ten seconds.

We have already seen in Chapter 11 that the earliest work on these new projects in Britain was mostly concerned with building preliminary test vehicles to explore the problems of aerodynamics, flight control and propulsion. But the intention was always to involve Australia as soon as possible, and early in 1948 the first scientists left LRWE to work with the British teams. In response to the MoS scheme to have industrial firms tackle the development of complete weapons, the Fairey Aviation Company had already started initial studies for the first air-to-air missile, a derivative of Red Hawk renamed Blue Sky. No other company showed much enthusiasm for what seemed at the time to be a very doubtful starter[3], but two other companies, English Electric and Bristol Aeroplane, did agree to set up sections to develop the Red Heathen ground-to-air missile. Though Red Heathen was being sponsored by both Army and Air staffs, who agreed about the performance they demanded of it, the Army wanted it on a mobile launcher for rapid deployment while the Air Force wanted it on static mountings for the defence of airfields. Accordingly English Electric worked on the Army variant, Red Shoes, while Bristol tackled Red Duster for the RAF. For ten years the two missiles were independently developed, virtually as rivals.

HOW THE TRIALS WERE CONDUCTED AT WOOMERA

During the first years of the 1950s nearly all of the new missiles were at the embryonic 'test vehicle' stage, when it was most convenient to do the initial flight trials at Aberporth despite all its disadvantages. But as the missiles developed further and their launching and instrumentation facilities were constructed at Woomera, most of the trials activity was transferred to Australia where the principal contractors were already setting up their dependent organisations. Aberporth never became outmoded; new projects and renewed development kept it constantly in use. For many years Woomera and Aberporth had complementary roles, each range doing the trials work most appropriate to its facilities.

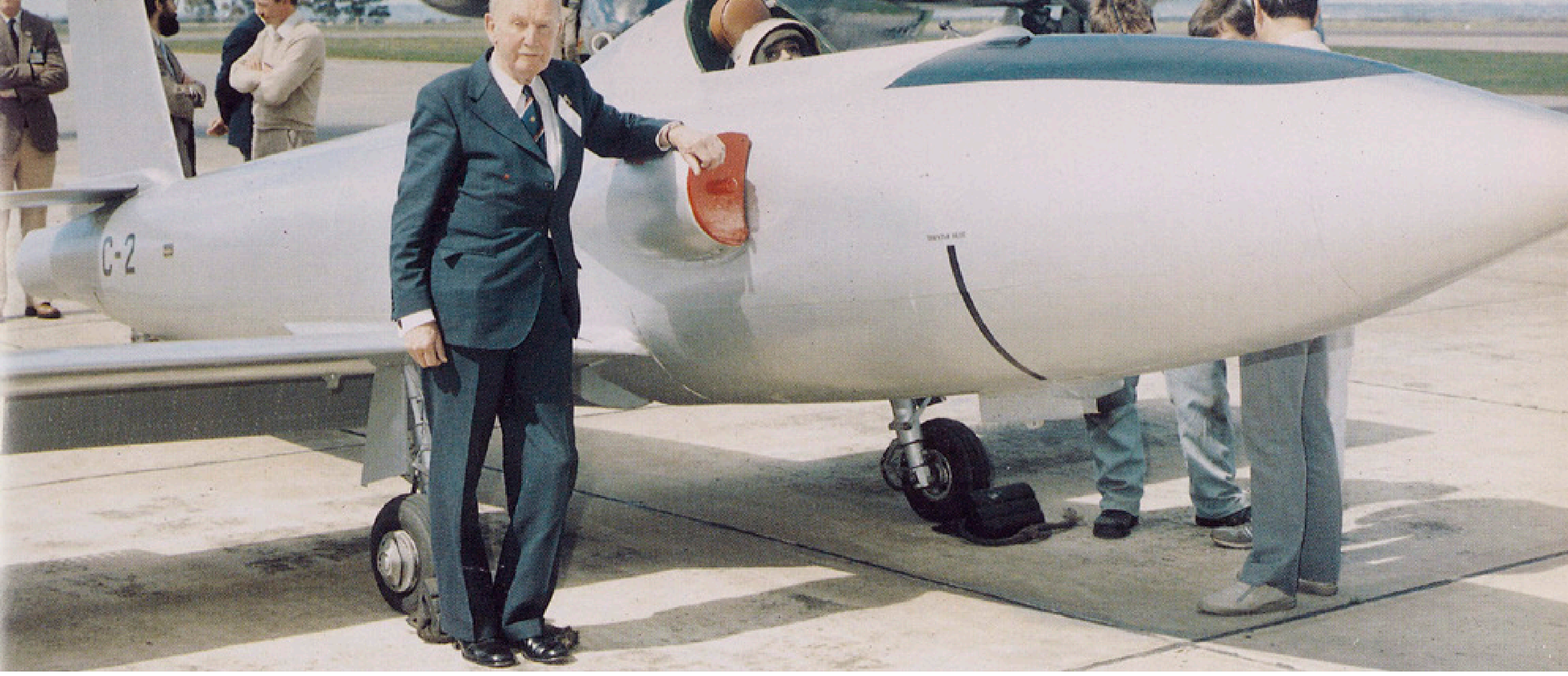
Trials programs at Woomera always followed the same pattern. They started with notification via CUKAC, followed by visiting missions, a planning specification which defined the work involved, an assessment of the cost, and application for approval under the joint project. Once approval was given preparations went ahead and in due course the trials began. First came an R&D or development phase, run by the contractor to expose unforeseen problems and achieve what engineers call a 'first design build'. In the early stages of this phase the contractor was given plenty of rope. Apart from overseeing the finances the Ministry of Supply kept its involvement as small as possible, though advice was freely available from the RAE specialists. Only in the latter stages, when the performance of the missile started to match the general terms of the operational requirement, did the Ministry start to watch the trials more closely and recommend which performance aspects needed to be improved.

Development—which was really a mixture of development and demonstration—was followed by the acceptance phase, where the trials were usually conducted by a special service team whose job was to determine whether the missile's performance was up to scratch. Such a team was called a Joint Services Trials Unit (JSTU), and was a detachment formed by the sponsoring service under a commanding officer, assisted by a scientist from the R&D establishments and by members of the contractors' staff. From 1962 onwards the term 'evaluation' replaced 'acceptance'. The terms were in part synonymous, but evaluation was a more comprehensive analysis in that not only did it show whether the missile met its operational requirement, but it also investigated the potential limits of performance under many conditions, no matter whether they fell short of or exceeded the requirement. The more inclusive approach of evaluation was possible because of advances in modelling; that is, using a specified set of flight trial measurements to validate a mathematical analysis. This method had been used to some extent from the outset. It had been advocated by Boswell as early as 1956 when he said 'we hold the view that the conventional statistical approach to acceptance trials (which basically gives a go-no go answer and which requires a large number of firings) is not an appropriate technique to apply to guided missiles'. WRE had already proposed, with some British support, a model approach to the forthcoming Blue Jay acceptance trials.[4] As time went on, greater computer power and a more refined technique permitted a fuller examination of a missile's performance range and superseded the 'pass or fail' results of the earlier acceptance mode.

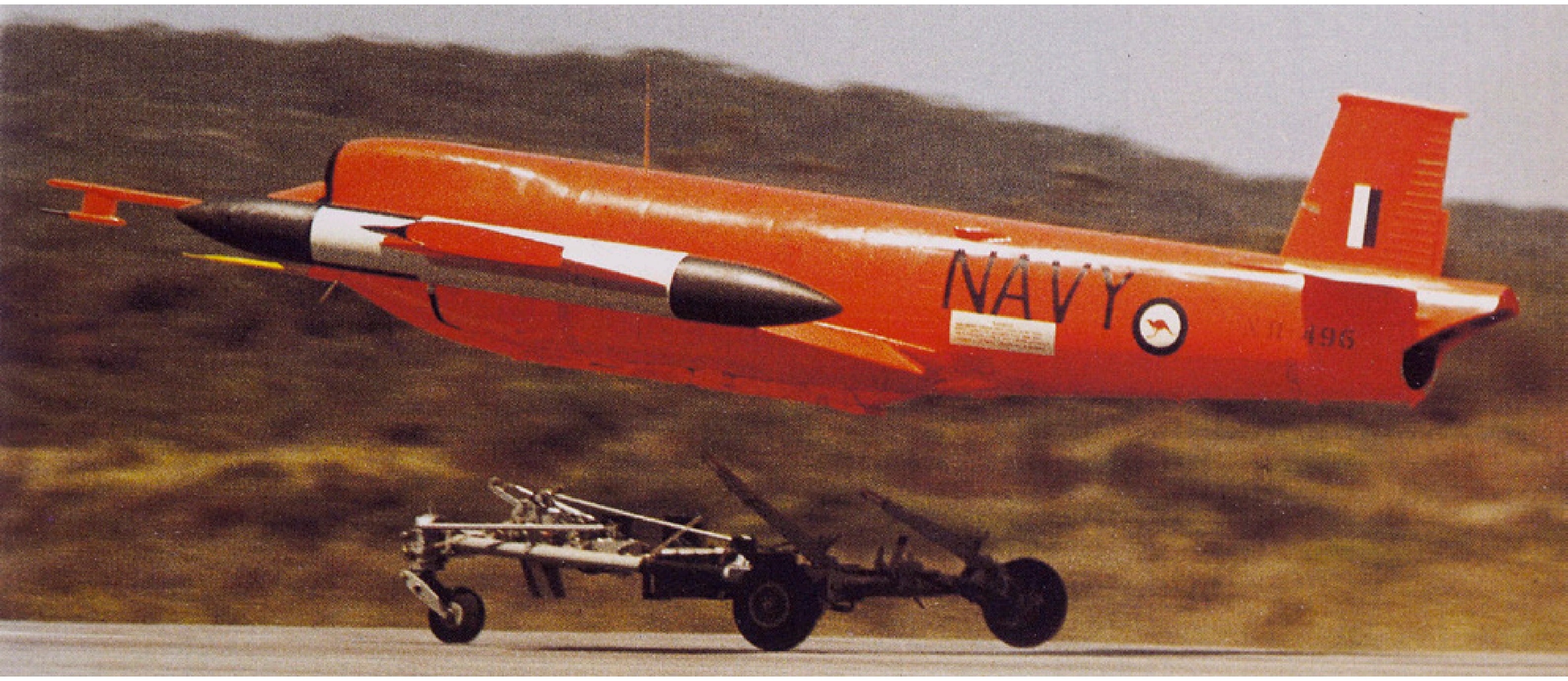
THE LITTLE MISSILES: AIRBORNE TRIALS

Compared with the lengthy programs of the larger ground-launched missiles, the air- to-air trials at Woomera formed a fairly compact series in which three different missiles passed through their flight test phases in the eight years after 1955. Blue Sky, in fact, won the race for the first guided missile project to be completed, followed by its more advanced successors Blue Jay and Red Top. The other early contender, Red Dean, was a very advanced design for its time but it had no opportunity to prove its capabilities as it was cancelled before its Woomera trials could begin.

Fairey's Blue Sky was by later standards an unsophisticated device, built in haste to meet an urgent RAF need; but still, as the first of a line, it was impressive enough. In appearance it was a slender pointed cylinder 2.2 metres long, with four large cruciform wings midway along its body and four small control fins at the rear. At launch, however, the missile itself was dwarfed by two huge solid propellant boost motors, mounted on either side and protruding well in front of the nose. Within a few seconds they accelerated the missile to over twice the speed of sound and were then jettisoned, leaving it to fly on as an unpowered dart over a maximum range of 3.5 kilometres. Blue Sky was a beam rider, and its accuracy depended on the radar of the launcher aircraft being locked on the target throughout—no easy matter.

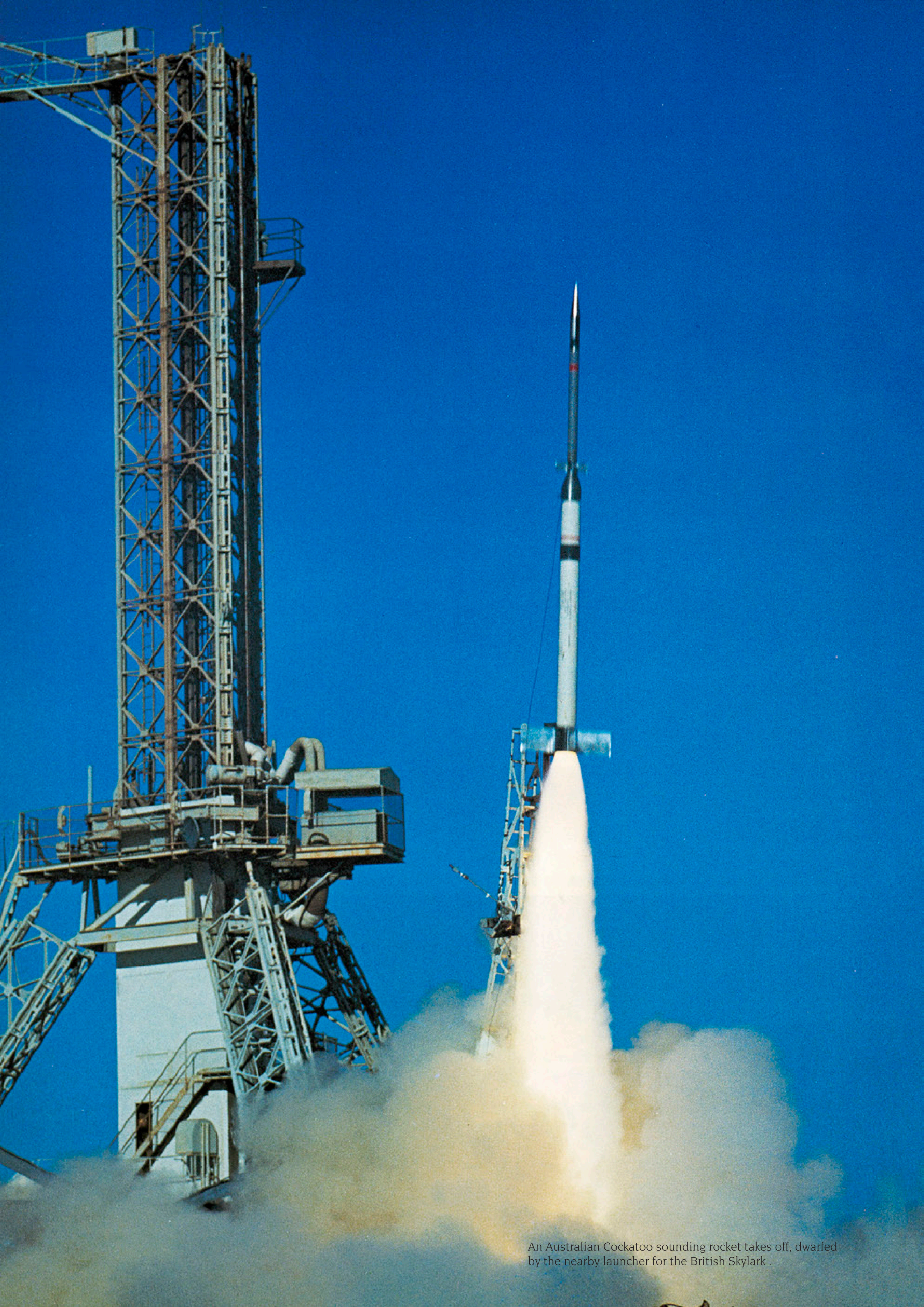


John Miles, former GAF test pilot, in front of the surviving Pika aircraft. In 1950 he became the first man to fly this manned prototype of Jindivik. (Aerospace Technologies of Australia Pty Ltd)

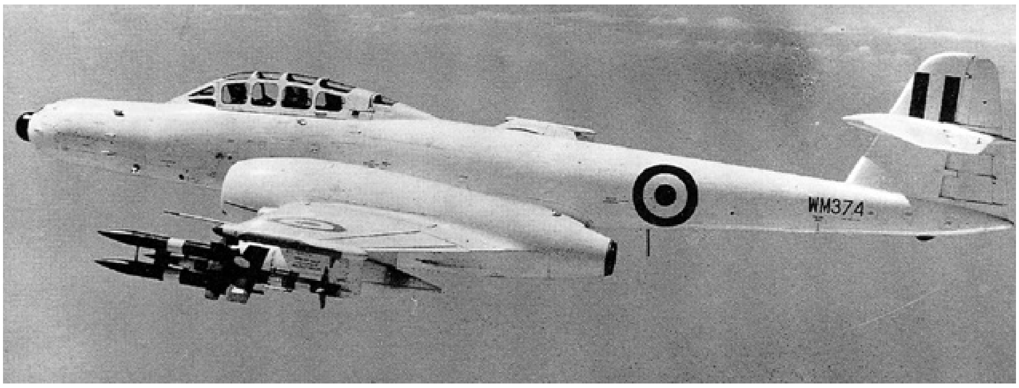


A Navy Jindivik takes off at the Jervis Bay Missile Range, New South Wales (Aerospace Technologies of Australia Pty Ltd)

Handing over the 500th Jindivik produced to UK representative Dr Roger Allen (*right*). (Aerospace Technologies of Australia Pty Ltd)



An Australian Cockatoo sounding rocket takes off, dwarfed by the nearby launcher for the British Skylark .



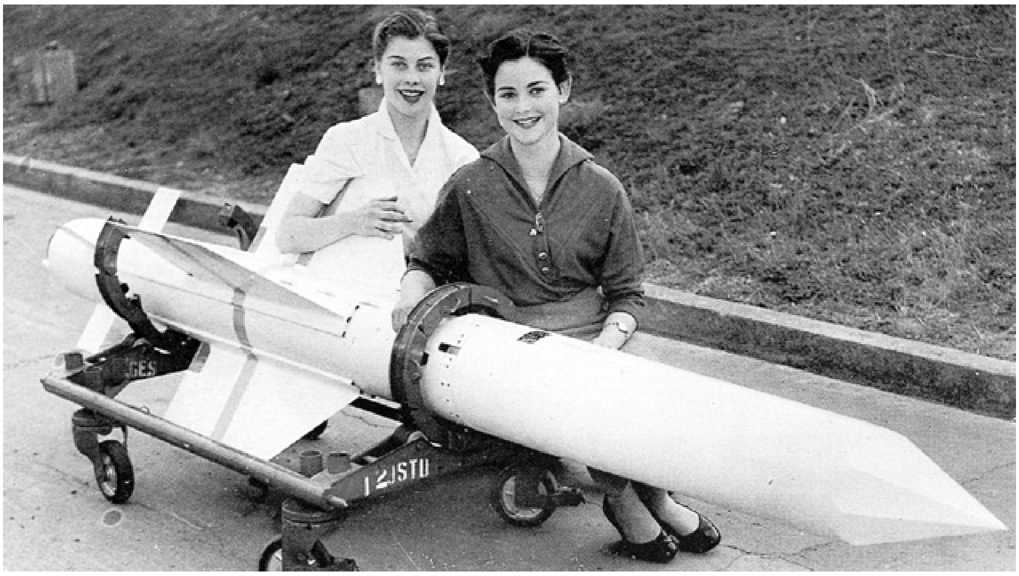
A Meteor NF11 night fighter carrying a Blue Sky missile under each wing tip.

Blue Sky first flew over Aberporth in 1953. Trials at Woomera began in September of the following year, when the first missiles were statically tested to check that their telemetry senders were compatible with the LRWE receiving equipment. The development trials were under way by March 1955, beginning with 'carryover' flights in which a manned aircraft took the missile down the proposed flight path to check the instrumentation and to do further telemetry tests. The trials continued until September with a full program of launchings from the carrier aircraft, a Meteor NF11 night fighter. To give the crew some launching experience the missiles were initially unguided with their control fins fixed in one position; but by August the first missiles were being flown under guidance, though unarmed. Pilotless aircraft were not available at the start, so a manned Meteor was used as the target for radar tracking and missile aiming. Naturally it kept well out of range! When Jindivik pilotless aircraft came into use as targets the results were good, with two firings giving miss distances of only 6 metres and 12 metres. Failures were numerous during the development trials, but with a success rate of 75 per cent ('success' being generally defined as a fair achievement of the trial objectives) it was considered expedient to proceed with the acceptance program.

A Joint Services Trials Unit (6 JSTU) had been formed in July 1954 and gained its initial experience at Aberporth. Its transfer to Edinburgh Airfield started in April 1955, and eventually the unit consisted of some forty-five officers and airmen including three pilots, one of whom was the Officer Commanding, Wing Commander A. C. Rawlinson.[5]

The first acceptance firings took place in September 1955, beginning with fixed fin missiles for familiarisation purposes. In December the first beam-riding missile was launched, but unfortunately its roll control was lost because of a small component defect. A pattern of other random problems continued through the forty firings of 1956. Perhaps the most disquieting failure was the tendency of the missile to slew violently from its course as soon as the boosts separated, a malfunction which had several contributory causes: firstly the loss of high pressure air to the fin actuators due to a faulty valve (discovered on examination of the debris after impact—proving the great advantage of range recovery), and secondly some aerodynamic and control deficiencies, cured by some modifications by Fairey.[6] On one occasion a Blue Sky slewed fiercely enough to rip its wings off, yet despite that it continued to ride the beam for another 16 seconds and actually hit the target aircraft. Rawlinson was uncertain whether to call this flight a success or a failure. The situation improved in 1957 with greater success as well as a high rate of firing; by early May, thirty-five beam riders had been launched. Near the end of the program a Blue Sky was given a warhead and sent against a Meteor target, the only time this was used, and it exploded 13 metres away, totally destroying the Meteor. This completed the acceptance trials, which had cleared a host of problems and provided sufficient data for the continuing mathematical simulation on the WRE analog computer AGWAC. The JSTU team returned to Britain in July. Blue Sky, under its operational name Fireflash, went into production and was adopted for limited service with the Royal Air Force as a training and indoctrination weapon.

Blue Jay, the second of the air-to-air weapons, was under design study by De Havilland Propellers in 1951. The missile itself looked much like Blue Sky, with its cruciform wings and rear control fins, although it was larger: over 3 metres long with a wing span of 75 centimetres. Otherwise the concept was quite different. Blue Jay lacked Blue Sky's large external boost motors; it was propelled by a single integral solid fuel motor which took it to supersonic speed from launch and did not separate. The guidance system used infra-red homing which brought Blue Jay to the target on an advanced proportional navigation



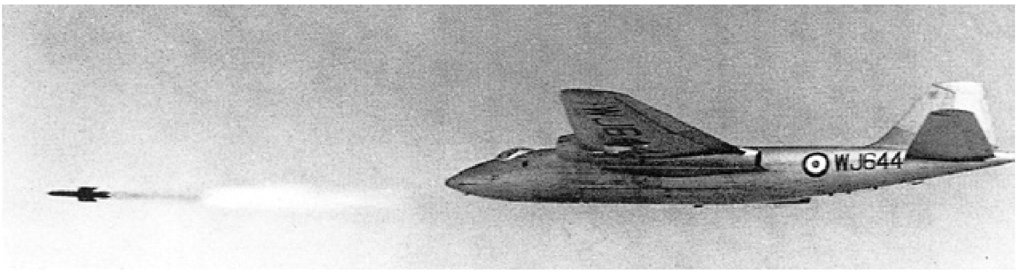
A Blue Jay infra-red homing missile

trajectory. The heat-sensing device was in the nose, protected by a very distinctive pointed cap formed of eight triangular panels transparent to infra-red radiation.

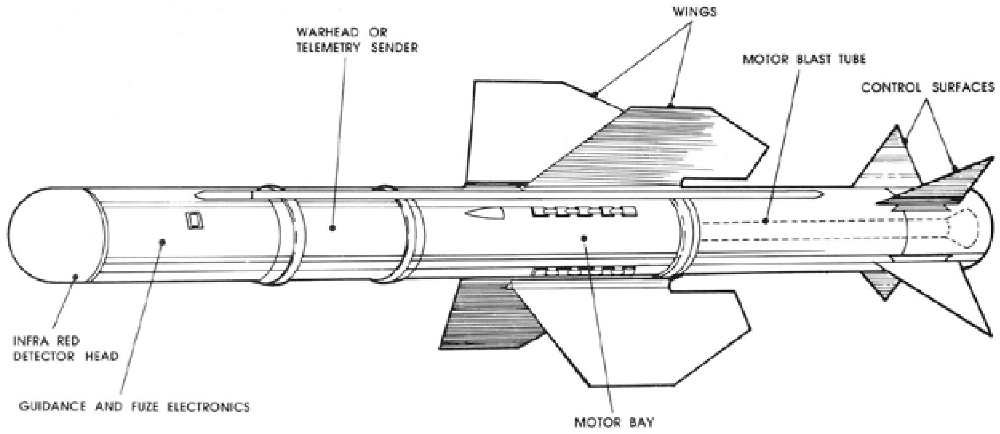
The early development of Blue Jay proceeded so rapidly that its trials program followed hard on the heels of Blue Sky; in fact the British planning mission of early 1953 came to LRWE prepared to discuss the Range facilities for both missiles. Aberporth handled the early development flights as usual from 1954, and a new unit, 12 JSTU, was formed in readiness for the future acceptance trials. The development program began at Woomera in May 1955, starting with the standard carry-over flights and the launching of six fixed-fin Blue Jays from pylons fitted under the wings of two CA-27 Sabre carrier aircraft. The opening successes seemed a good augury, but it was not long before persistent difficulties and delays began to appear. More instrumentation became necessary in the zone of the Range where the target was intercepted, and this meant extra Contraves kinetheodolites which were not immediately available. It was November 1955 before the trials could resume with more carry-over and fixed-fin launchings and in April 1956 the first attempts were made, unsuccessfully, to launch missiles equipped with a full guidance and homing system. At this point the work was brought to a sudden halt by an appalling accident. During the afternoon of 19 April the missile launching circuits of a Sabre aircraft were being checked in Hangar 3 at the Tech Area. Suddenly a Blue Jay missile mounted on the Sabre's port wing fired without warning, hurtling across the hangar and bursting through the far wall into an external revetment, where it disintegrated in a shower of burning propellant. Two De Havilland team members were standing beside the missile as it ignited. One of them, Tom Lister, was killed by the flame and blast. The other, John McLoughlin, was badly injured. By a bitter coincidence a party of six visitors led by Trials Superintendent Jim Price entered the hangar to the rear of the aircraft just as the Blue Jay fired, and several were severely burned by the efflux. There were of course no further firings while the accident was investigated. The inquiry concluded that the cause was an electrical defect. The safety plug, which was inserted into the firing circuits during testing, created a short circuit which was normally effective enough; but in conjunction with another defect such as an insulation failure it could allow ignition to occur. This is apparently what had happened.[7] Though it was little consolation to the injured, the cure was simple enough.

By the end of May the guided trials were allowed to continue, still unsuccessfully at first. Better results were achieved in July; four homing missiles were launched successfully and passed close to their targets. None of these Blue Jays was armed, but one damaged a Jindivik with a direct hit.

The British members of the De Havilland team then left for home while new laboratory facilities and accommodation for the Blue Jay JSTU were being constructed at Salisbury. The next development phase began on their return in November 1956, assisted now by 12 JSTU which was established at Edinburgh Airfield under the command of Wing Commander A. J. Strudwick. Further problems soon appeared: a large number of flight sorties was attempted, only to be aborted by faults in the missile, the target or the Range instrumentation. But



Launching a Blue Jay from an RAF Canberra during acceptance trials.



The Red Top air-to-air missile, which replaced Blue Jay.

there was a gradual improvement from March to July 1957, bringing general agreement that Blue Jay's acceptance trials could begin.

The trials conducted by 12 JSTU began inauspiciously in September. After one firing, unsuccessful because of a control failure, it was found that none of the stock of missiles would pass pre-flight tests and most of them were sent back to Britain for correction. The acceptance firings then recommenced in November and continued until April 1958, interspersed with occasional development trials. This was a relatively happy period, when it seemed that the teething troubles were over at last. But the satisfaction was premature. Two of the failures had come at the high altitude of 42 000 feet when the missiles lost their control stability, and three more failed similarly in May. Experiments started anew to find a cure, and this entailed a reversion to development trials. Several modifications were introduced, particularly to the control system actuators which were suspected of being the source of the trouble, but seven more high altitude launchings in October to December gave only one clear success. It was not until nearly a year later, towards the end of 1959, that it could be claimed that the problem was solved. A new design of actuator was put through rigorous tests, including ones at very low temperatures, before being fitted.[8] Twenty of these modified missiles were launched at high altitudes, with only three failures. Five Blue Jays scored direct hits on the target aircraft. 12 JSTU returned to Britain early in 1960 with the acceptance trials at last over. Blue Jay, under the new name of Firestreak, continued in production until 1969 and went into RN and RAF service on Sea Vixen, Javelin and Lightning aircraft.

In 1957, when the acceptance trials of Blue Jay were about to start, the design of its replacement was already being studied by De Havilland. The new weapon was called Red Top. Outwardly it strongly resembled its predecessor, and indeed was initially called Firestreak Mk 4. It had the same configuration of cruciform wings and control fins but was slightly longer and had an increased wing-span. Like Firestreak it homed on infra-red radiation, though it had a much better detector under a hemispherical nose cap which gave a much wider angle of target acquisition and attack. The internal solid fuel motor had higher power, capable of taking Red Top up to Mach 3.

Woomera had a smaller role to play in Red Top trials than in those of previous weapons; most of the work, including acceptance trials, was done in Britain. The WRE planning specification issued in October 1959[9] listed a development program of twenty-five to forty firings to begin by mid-1960. Despite some delays the program began reasonably well. The launcher aircraft—two Sea Vixens—arrived in June and September 1960, and 13 JSTU was present for the first two firings before the end of the year. To begin, the usual fixed-fin missile was launched, followed by a fully guided weapon in December which missed the

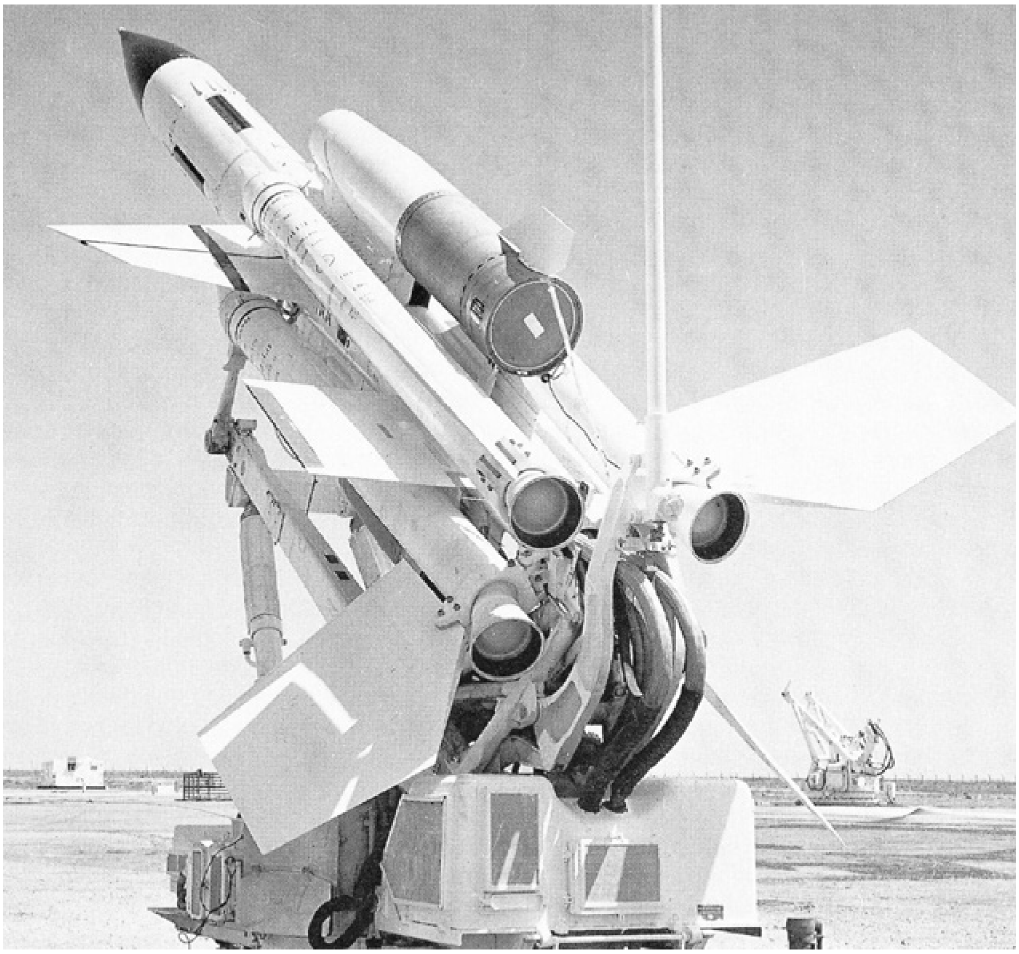
Two Sea Vixen aircraft used for Red Top trials, on the tarmac at Edinburgh.

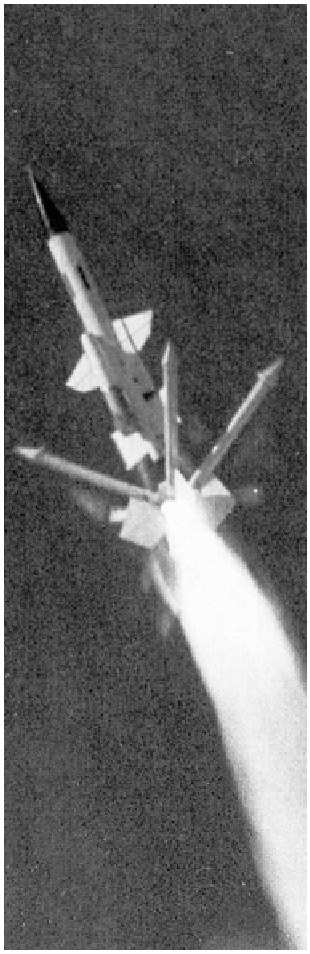
Jindivik target by less than a metre.[10] Trials progress in 1961 was marred by delays, mostly due to problems with the launch aircraft and its sophisticated missile-firing computer, and many sorties were aborted for this reason. During the year nine missiles were fired, deliberately arranged to provide difficult homing conditions with large deviation angles; even so, five came close to the Jindivik, including one direct hit. The same rate of success continued in 1962 to the end of the development program, although rather ironically the last three firings failed. This completed the trials at Woomera. Red Top was eventually accepted by the services as a phased replacement for Firestreak on Sea Vixen and Lightning aircraft.

Red Dean has already been mentioned as the fourth member of the air-to-air quartet. It was an early development, appearing on the scene soon after Blue Sky and Blue Jay, yet it had a complex design for the period, particularly in its guidance system which used the active homing principle. Red Dean was the first of the joint project weapons to use this principle, and both its range and explosive power were designed to be greater than those of either of its contemporaries. Folland Aircraft, the prime contractor, had the first design studies for the missile underway by 1950, but Folland withdrew in 1951 and the contract was transferred to Vickers-Armstrong plus a number of subcontractors including Smith's Aircraft Instruments, GEC and EMI. The basic configuration of the missile remained unaltered; with its cruciform wings, rear control fins and internal solid fuel boost motor it was essentially the same as Blue Jay and Red Top, except that it was much larger than either. In the course of the studies, six different designs were produced (two by Folland and four by Vickers-Armstrong) with only minor dimensional changes.[11] The final Vickers configuration, designated WTV5, had a length of nearly 5 metres and a body diameter of 32 centimetres—half as big again as Red Top. In February 1954 Vickers produced their flight trial program[12] which was to start at Aberporth later that year, followed by development trials at Woomera from October 1955 and acceptance in 1956-57. The WRE planning specification was produced on this basis and the program accepted as a joint project task.

The planned firings did not take place in 1955, as the Canberra aircraft that was to carry the missile had to be modified for the purpose. And as the months passed, there were indications that support for the project was diminishing. Sir Steuart Mitchell pointed out during discussions in April 1956 that Red Dean was designed exclusively to equip a future supersonic all-weather fighter, the thin wing Javelin, which was itself experiencing design problems and had an uncertain future. He warned that the project was therefore fluid and might lapse.[13] Yet at the same time, as if to buoy up hopes, future trials of an advanced version of Red Dean, Red Hebe, were postulated. They came to nothing. Within two months, Red Dean was 'no longer an operational requirement of the Ministry of Supply'[14] and the project was cancelled, along with the evanescent Hebe. The Canberra launch aircraft was put back into its original state and returned to Edinburgh Airfield. Vickers-Armstrong's last act was to supply a finale in the shape of a complete compendium of Red Dean design. This was little consolation to the 800 workers at Vickers who lost their jobs[15] but the document duly appeared, forming a comprehensive and valuable record. It included its own sardonic epitaph:

> The biggest difficulty facing the contractors was the large variety of interested Ministry and Service Departments who, while not having to do any design, had a hand in design decisions.[16]





GROUND-TO-AIR MISSILES: THE HEAVY TRIO

Above left: Bloodhound Mk 2, an RAF anti-aircraft missile, on its launcher at Range E in 1964. The Mk I version was known as 'Red Duster' during its early Woomera trials.

Above: Jettisoning the boost motors.

It has already been described how the early missile concept called Red Heathen preceded three separate missile projects, in effect one for each of the three armed services. The resulting projects—Red Duster (later Bloodhound), Red Shoes (Thunderbird) and Seaslug—each with its line of successors, had a greater endurance at Woomera than almost any other. They lasted for twelve years; and Seaslug, after a lapse of five years, came back again for another series of improvement trials.

The design of Red Duster was begun in 1949 by two principal contractors, Bristol Aeroplane and Ferranti, who together provided the necessary expertise in aircraft design and electronics. The relationship was potentially a tricky one. A. R. Adams describes how representatives of the two companies were introduced by Sir George Gardner:

> they circled suspiciously round each other and each came somewhat reluctantly to the conclusion that the other was perhaps fairly all right—with a few reservations.[17]

After this the companies got on well; the joint design studies progressed quickly and in 1951 Britain made its submission to CUKAC for the ground-to-air weapon trials which were accepted by the joint project in the following year.

In its final design Red Duster (which was to become the RAF weapon) looked very much like the product of an aircraft company. It had the usual slender body, about 6.7 metres long and 55 centimetres in diameter, but only two lateral wings in the style of a monoplane and a small fixed tailplane at the rear. The wings were pivoted, so that they could control roll motion by differential movement, and pitch by moving in unison: ordinary aircraft use the same 'twist and steer' method. The missile was boosted at launch by four externally attached ('wrap round') solid fuel motors which were jettisoned at burn-out, leaving the missile under the sustained propulsion of two ram jet engines mounted externally above and below the main body. Guidance was of the semi-active homing type. The Red Duster trials began with test vehicle firings at Aberporth, using RTV2 vehicles with their four wrap round boosts, which provided firing experience for the newly formed contractors' team, together with some practical research into guidance and propulsion techniques. Bristol-Ferranti continued the step by step development with a series of five of their own test vehicle designs, under the code names XTV1 to XTV5, and in mid-1953 the first Woomera firings took place using three XTV4 propulsion test vehicles. Only one could be counted as successful, but the men of the Red Duster project took great satisfaction from having outstripped its two rivals in the race to Woomera.

For a few months there was a lull while permanent launching facilities were being planned and built. The next vehicles to arrive at Woomera were type XTV5, which closely resembled the final Red Duster design. Elaborate instruments on the XTV5 included on-board cameras to photograph the separation of the boost motors, and the temperature of the missile skin in flight, especially at the ram jets' efflux, was recorded by temperature sensitive paints. Thus it was important to recover the missile parts after impact. The first firing in February 1954 presented some problems in this respect. The automatic propellant cut-off failed and the missile flew on until its fuel was exhausted—at a speed of Mach 2.7 to a range of 45 kilometres. Fortunately it landed in a dry salt lake where the spotter aircraft located it.[18] Altogether, nine XTV5 missiles were launched that year, and the program continued at the same rate through 1955 with considerable success.

Major john Hotham, longest serving CO of the Army Guided Weapons Trials Unit at Woomera.

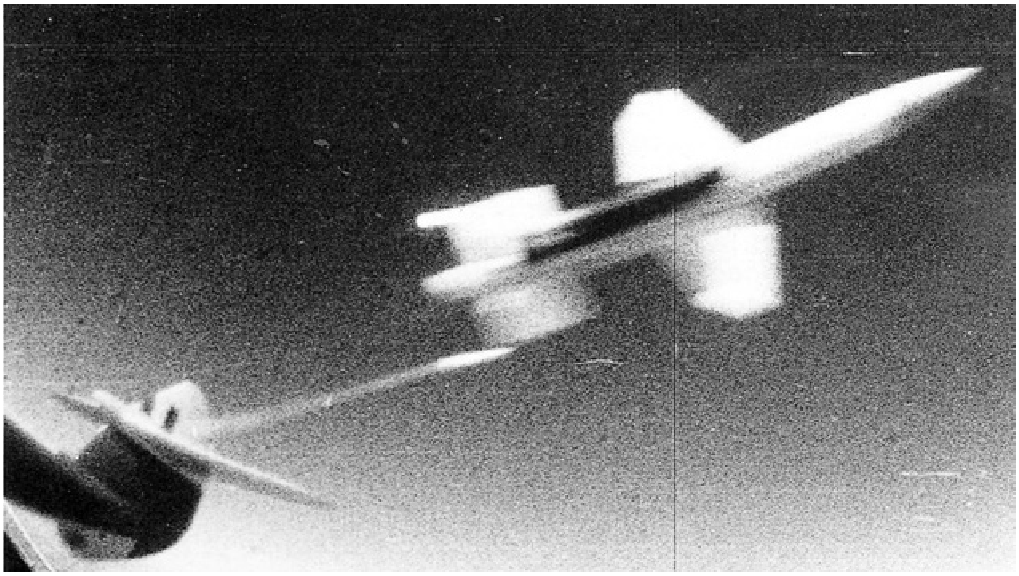
The time had not yet come for the presence of British Army teams at Woomera, but a detachment of the Royal Australian Artillery was already taking a large part in the trials work. In 1954 the Army Guided Weapons Trials Unit was set up under the command of Lt Col A. G. Cairns, with responsibilities for missile preparation and launching and for radar maintenance and operation. The unit brought an Australian service complement to the Range staff for the Red Duster trials, and subsequently for Red Shoes, Seaslug and virtually all the major project trials until 1973.[19]

In early 1956 flight trials of a specialised variant of XTV5 took place. The missile was called the Controllable Recoverable Re-usable Test Vehicle (CRRTV, or Bobbin for easy reference) and its main purpose was to test a new ram jet engine which had to be recovered undamaged. To achieve this, the missile's descent was slowed by two parachutes deployed in sequence, and the shock at impact was reduced by a long nose spike, which was supposed to leave Bobbin sticking vertically out of the ground like a dart in a carpet. To test the system, three Bobbins were dropped from a Lincoln aircraft. The first worked perfectly, while the other two suffered a failed parachute and a broken nose spike. Three more were then launched, this time from the ground in a boosted flight. Only one was a perfect success, being found by the recovery team sticking up on its spike with its parachute billowing out like a spinnaker. Its spectacular appearance did not prevent Bobbin from being cancelled at this point.

Meanwhile, the Red Duster trials program continued to the end of 1956 with eight more launches including the first two against Jindiviks. Neither was successful, due to a loss of radar control soon after launch. Other flight experiments had rather better fortune. As well as the propulsion tests, a firing in July 1956 was arranged to check the erosive effect

Right: Recovery of the Bobbin test vehicle, a precursor of Red Duster.

Below right: WRETAR camera photograph of interception during a Red Duster acceptance trial in 1958. This encounter was close enough to damage the Meteor target.



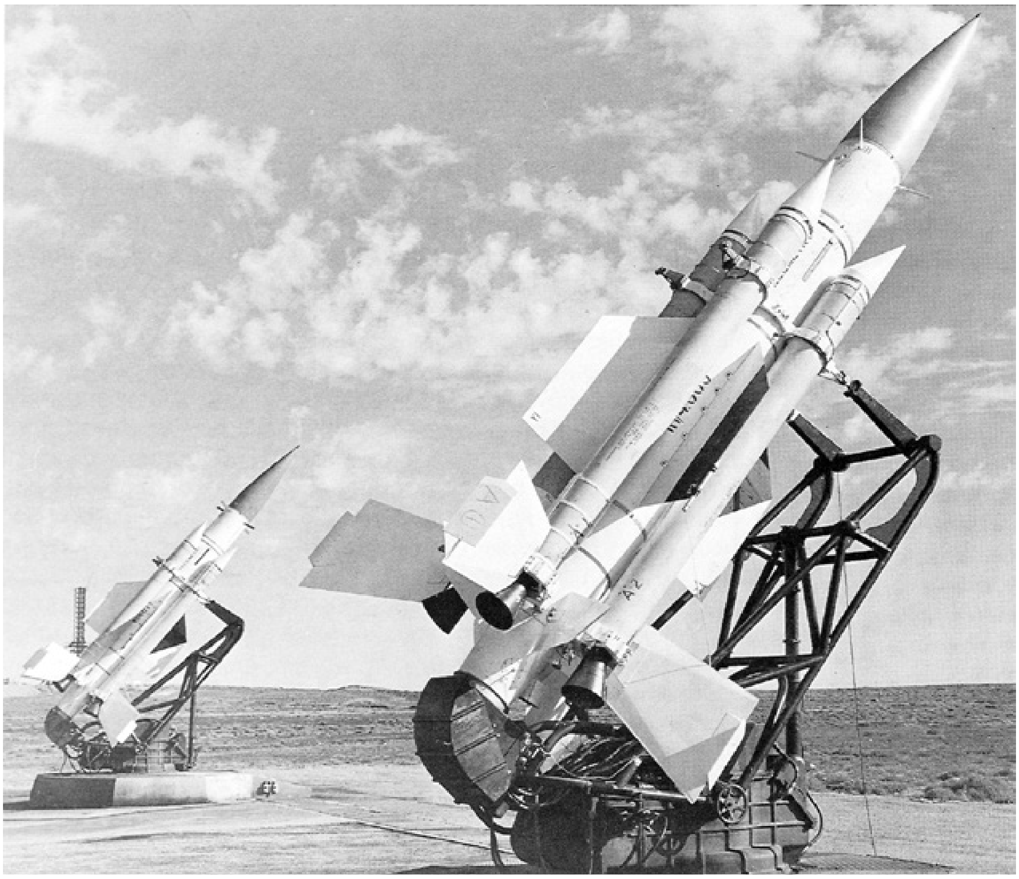
of heavy rain on the delicate nose cap of the missile. This cap formed the 'radome', and was made of special material to allow radar signals to pass through to the internal receiving aerial. As it happened, the test missile had lingered at Aberporth awaiting suitable wet weather, which amazingly never came at a convenient time. (The missile was even equipped with flotation bladders so that the debris could be recovered from the sea for examination.) At length it was sent to Woomera where ironically, and most unusually, the desired heavy rain appeared in abundance.[20] The test results were deemed satisfactory, although on this occasion the ram jets misbehaved, reducing the expected flight speed.

During 1957 the services team, 8 JSTU, was formed in readiness for the scheduled Red Duster acceptance trials. There was a lull in the firing program until August, when the development flights recommenced with familiarisation firings by the service unit. These were disappointing; there were numerous failures of the radar link to the missile, and also a tendency for the ram jets to cut off prematurely. Ferranti staff worked hard to solve the radar problem, with their development firings interspersed with service acceptance trials until the end of 1958. The ram jet cut-off problem continued in the trials of 1959, but by September the Bristol company had analysed the cause as a matter of aerodynamics: the angle of the missile's body to its line of flight became too great for the ram jets to take in enough air. A solution followed with adjustments to the missile tailplane and control system.[21] At the end of the year the acceptance trials were nearly over and most of the JSTU staff returned to Britain. The remaining few trials of armed missiles were completed by a small combined team in April and May 1960.

Red Duster, now called Bloodhound Mk 1, was adopted by the Royal Air Force even before the acceptance trials were concluded; it was installed as an operational system in October 1958 at the North Coates RAF base in Lincolnshire. In November the Australian Minister for Defence announced that the RAAF was also to be equipped with the weapon, adapted slightly to meet Australian conditions. A RAAF base at Williamtown near Newcastle, NSW, was chosen for the first installation, to become operational by the end of 1962. Meanwhile, planning was already well under way for an improved version of Bloodhound. As early as 1955, Bristol and Ferranti were at work on a super long range (320 kilometres) variant, to be called 'Bloodhound stage 1¾' or Blue Envoy.[22] In the Bristol tradition it had aircraft-like characteristics, with a 5-metre wing-span and a length of nearly 8 metres. Scale models were built and flown, and in April 1957 a combined mission came to WRE to discuss trials planning. Although the project was cancelled at this point, the joint contractors were quick to propose two alternative developments of Bloodhound Mk 1: QF169, which employed an advanced continuous wave (CW) radar system (with greater immunity to ground echoes and disruptive interference); and R0166, which would be guided by ground command. Both versions were discussed with WRE at a planning mission in May 1959, but R0166 did not survive; it was cancelled the following April, leaving QF169 to be developed as Bloodhound Mk 2.

The QF169 test vehicle trials began remarkably quickly at Woomera, overtaking the final stages of Mk 1 acceptance. The first ram jet test vehicle, XTV12, was successfully fired in November 1959, and the second followed in May 1960. However, the majority of the development flights took place at Aberporth, while Woomera concentrated on special experiments particularly where recovery was important. In the event, development trials remained in progress at Woomera concurrently with service evaluation (as acceptance was now called) almost until the end of the Bloodhound Mk 2 program. But after the expeditious start some long delays occurred while the ground radar was first modified and then replaced by a superior type known as Red Brick, and while more telemetry and Contraves kinetheodolites were being installed at new posts further down-range. Homing missiles were fired at aircraft targets in October 1960 and May 1961, and under the guidance of the new CW radar scored a direct hit on a target Meteor. From this time development firings continued intermittently, on average about one or two each month, until late 1964.

The service trials unit, 15 JSTU, arrived at the end of 1961 to prepare for the evaluation trials. Their first task was a lengthy one—to check out the launching complex together with a new radar, Indigo Corkscrew, which was being installed as a further improvement on Red Brick. Evaluation trials began in December 1962 and continued at a fairly steady rate until April 1965, covering a whole range of interception conditions to prove the missile performance and to provide data for the mathematical model. They exposed various faults in the missile system, including structural failures causing wing loss and break-up soon after launch. The Indigo Corkscrew radar became subject to high noise interference, requiring a visit by



Two Red Shoes telemetry missiles on their launchers at Woomera.

Ferranti and Royal Radar Establishment Malvern staff for rectification. Finally, a 'boost blast' phenomenon was observed, when the efflux from the powerful boost motors disrupted radar tracking. To investigate this effect, a series of dummy RS-D missiles with active boost motors was launched, known colloquially as 'flying bricks'. With the completion of evaluation in 1965, 15 JSTU returned to Britain, leaving the mathematical analysis and modelling work still in progress at WRE. Bloodhound Mk 2 had already been accepted by the RAF to supersede the Mk 1 version, and both Sweden and Switzerland had ordered the missile system.

Although Red Shoes was developed by a different prime contractor, its career closely paralleled Red Duster's in both the nature of the program and the time it took to complete. English Electric of Luton undertook a design study for the missile in 1949 and received a development contract in the following year. Red Shoes looked more like a conventional missile than its rival, with a cruciform arrangement of four fixed wings at its centre and corresponding movable control fins at the rear. The missile body, 6.3 metres long and 55 centimetres in diameter, was rather shorter than Red Duster's. The boost consisted of four solid fuel motors fitted round the body, but the type of internal sustainer remained undetermined for several years. Because of the poor performance of solid fuel motors at that time, English Electric initially proposed a liquid fuel rocket engine using concentrated hydrogen peroxide (HTP) and kerosene, but this was eventually superseded by a solid fuel sustainer as propellant technology advanced.

The first flight tests took place at Aberporth, starting with a liquid fuel version, D3, in 1951, and progressing over the next few years to the solid sustainer D4. At the same time, arrangements were in hand for a development trials program at Woomera. A technical mission to WRE in March 1953 worked out the details of the launching installations, which were soon being constructed and were ready for use by the following year. For early proving trials, starting in April 1954, D3 missiles were launched; but in December the first type D4 was successfully flown with a solid sustainer named Ratcatcher. From then on the firings continued with variable success at intervals of about a month. The liquid fuel version was soon discontinued with a final D3 firing in March 1955 leaving the solid fuel motor as the chosen means of propulsion. With this basic decision made, the actual type of solid fuel motor remained the subject of experiment. Two further designs named Smokey Joe and Elkhound were used in the course of development.

The year 1956 brought some interesting development flights. In February the first fully guided missile (using semi-active homing) was fired in Australia, at a stationary target consisting of two metal spheres 2 metres in diameter suspended from a balloon.[23] Unfortunately it was a failure because steering control was lost in mid-flight. A later firing broke up spectacularly just after launch. In general, failures exceeded successes over the year but there were several redeeming events, including the first flight in April of a W1 missile which represented the final design of Red Shoes. Then in November, the first homing missile was successfully fired at a Jindivik; it was an exhilarating result for the Red Shoes team, especially as Red Duster twice failed in a similar attempt at about the same time. The trials results through the following year gave no further cause for elation. The failures included six missed shots at Jindiviks and two unsuccessful attempts to hit the stationary balloon target. This was enough for the time being. The acceptance trials, scheduled to begin in 1958, were postponed for a year while English Electric and the British establishments held an inquest which concluded that no single factor was causing the failures. There were many small defects in design, manufacture and inspection which required individual attention.[24] When the Red Shoes trials were resumed at Woomera in mid-1958, the benefits of the remedial work were obvious. Oddly enough, the first two of the series failed structurally for a new reason: the loss of one or more fins due to flutter. This fault was cured by fitting a balance weight on the fins' leading edges. The next eight firings were all successful.

The Red Shoes acceptance program began in March 1959, carried out by 8 JSTU which was already at Woomera conducting the Red Duster trials. The unit at that time was composed of RAF and Army staff, but in October when Red Duster acceptance was nearing completion the RAF contingent was withdrawn, leaving the Army as 8(A) JSTU in charge. Throughout the year the trials were consistently successful. Although the missiles carried telemetry transmitters instead of warheads, their lethality was convincingly demonstrated. The intercepted targets included Meteor jets flying high on a crossing path and Canberras on a fast weaving flight. The program was completed by June 1960 and only two failures occurred—due to an error in preparing the hydraulic system filters in the missiles after storage during the Range stand-down over Christmas. 8(A) JSTU was able to return to Britain well satisfied with the results of the team's efforts. Red Shoes, under the more evocative name of Thunderbird Mk 1, came into service with the British Army in the same year.

The first indications from Britain of an improved successor to Red Shoes were given at a CUKAC meeting in October 1956. Five months later, when Red Shoes was struggling with its reliability problems, a planning mission visited WRE to discuss range requirements for the newcomer, to be called Green Flax. Green Flax was to be similar to its predecessor, although larger and with a greatly increased range and pursuit performance, and it would use the CW type of radar which was later adopted for Bloodhound Mk 2. The title Green Flax was discontinued in November 1957 when somehow it had become compromised and the project was reborn as Yellow Temple, although its technical development was unaffected. The first test vehicle, a modified Red Shoes, was launched at the end of 1958, and ten more experimental firings took place in the latter part of 1959 to prove the upgraded propulsion and control systems. At this time another name change was imposed, brought about by a redefinition of defence policy which allocated the Thunderbird development specifically to the Army, while the RAF retained Bloodhound.[25] The project was now called VR725. The only major technical change was that the maximum operating range and altitude were reduced from the original Green Flax specification, although they continued to be greater than those of Thunderbird Mk 1. After this diversion the development trials continued unabated with the service unit 16 JSTU (about seventy Army personnel) present at the last firing, which was memorable for destroying a Jindivik at 55 kilometres range.

The evaluation program was slow in starting, with ground equipment problems occupying the time and efforts of the Army unit; and several of the resulting failures in 1962 were attributed to poor performance of the Indigo Corkscrew radar, a problem which was also affecting the Bloodhound trials. There was a short reversion to development work in 1963, and then evaluation continued through the year to its scheduled conclusion in May 1964. Apart from mathematical modelling, this was supposed to be the end of the Thunderbird Mk 2 program, but the analysis of results showed some discrepancies which demanded attention and further flight trials. Foremost was the apparent failure of the warhead initiation circuit and proximity fuze to work properly. At a mission to WRE in November 1964, a further short program of 'additional evaluation' was agreed upon.[26] Six missiles were launched between May and November 1965 to investigate warhead actuation, instrumentation and finally the 'boost blast' effect which had already been encountered in the Bloodhound trials. With this, the program ended, 16 JSTU disbanded and Thunderbird Mk 2 entered service with the British Army.

The third member of the large anti-aircraft trio was Seaslug, the shipborne missile for the Royal Navy. Having the greatest priority of the three weapons, it was first to reach the stage of a firm development project. In 1947 the design studies were well advanced at government establishments, where Seaslug was unique in that certain parts of the design work had been contracted out to industry. The UK Directorate of Guided Weapons (DGW) called for an immediate extension of this industrial commitment:

> The target date for the introduction of an anti-aircraft guided weapon into the Navy is such that the major characteristics of the design must be frozen in the near future, and consequently it is necessary to proceed actively with the Industrial development of a rocket-propelled beam-riding missile.[27]

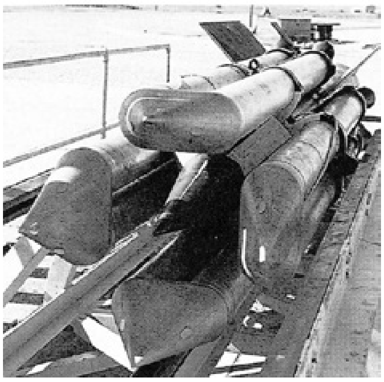
Thus it seemed that the beam-riding guidance method for Seaslug had already been decided upon, although RAE still had some reservations in their assessment of the missile system:

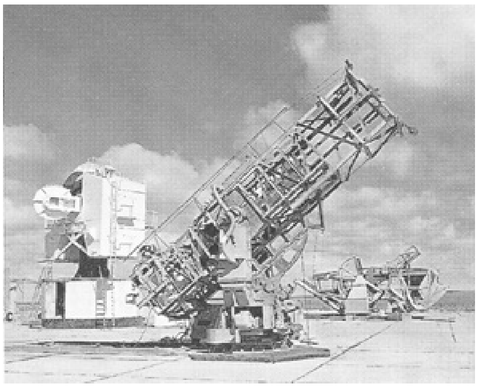
> Insufficient data are available to permit a determination of the optimum overall guidance and control system, and the right is reserved to postpone the final choice until research on alternative systems and on homing is completed. This is estimated to require at least two years . . . Liquid fuel rocket propulsion is preferred at this stage, but the possibility of changing later to ram jet propulsion must be recognised.[28]

However, by 1949 the Directorate reported that Seaslug was definitely to be a beam-rider, although the option was still retained of substituting a homing mechanism later. It was to use an unpleasant combination of kerosene and nitric acid as its propellants.[29] (As with Red Shoes, solid fuel sustainer motors were judged inadequate in the early stages.) Armstrong Whitworth Aircraft headed a consortium which included GEC to produce the guidance system and Sperry Gyroscope the flight controls. Since Seaslug was to be a naval weapon the handling and launching arrangements on board ship demanded special attention, particularly the stowage of the missiles in the magazine and the effects of boost efflux on the ship's superstructure. This aspect was assigned to Vickers-Armstrong.

Seaslug was in shape very similar to Red Shoes; it was slightly smaller but it had the same cruciform wing and tail fin arrangement with a group of four external boosts. The obvious difference was the position of the boost motors, which, unlike those of Red Shoes, were mounted at the forward section of the body, extending almost to the tip of the missile with their jet nozzles adjacent to the wings. The venturi were angled outwards to direct the

A Seaslug Mk 1 blasts off.





Far left: The eight boost STV on its launcher rails.

Left: The Seaslug launcher and GMY(1) guidance radar in 1962.

efflux away from the body. The reason for this positioning was apparently aerodynamic —it avoided the need for wide stabilising fins on the boost motors, and probably reduced the flame envelopment of the ship's launcher as the missile took off.

The first Seaslug firings were at Aberporth in 1949, beginning as usual with simple test vehicles. The program did not begin in earnest at Woomera until 1953, except for a short prelude in April 1950 when two boosted Seaslug dummies were fired at Range G to train the staff in handling large missiles. The next launches came in June and July 1953, and were of three Separation Test Vehicles (STVs) fired by LRWE at the prime contractor's request. These were again Seaslug dummies with an abbreviated body of 5 metres, each with its set of jettisonable boost motors. In this case, though, the STVs had eight external motors coupled together in pairs. The boosts separated when they ceased thrusting; air drag forced them backwards, locking pins released, and the empty canisters fell away. All three STVs flew and separated correctly, although secondary experiments using recovery parachutes failed.[30]

Throughout most of 1954 men of the Royal Australian Navy dockyard at Williamstown were building the new Seaslug launchers at Range E, and before the end of the year representatives of the contractors were at Salisbury. Armstrong Whitworth fired the first RS-D missile in November; a Motored Test Vehicle (MTV) with a liquid fuel engine which performed remarkably well in most respects. But the second MTV in December was a messy business. The nitric acid oxidant was contained in a polythene bag which leaked during filling, so the MTV was launched 'cold'; that is, with the boosters but without the sustainer operative.[31] The boost phase was satisfactory, but the telemetry failed and the trial yielded little or no information.

During 1955 the new guidance radar type GMY(1) was installed and tested by Australian scientists and the RAN. But as far as trials were concerned the results were dismal. Unreliability in either guidance or control systems was a persistent problem and only eight missiles were launched between July and December. Most of them used solid fuel sustainers which were now being introduced and were generally preferred. Of the two liquid fuelled Seaslugs, one behaved well but the second ignited before take-off, bursting into flames on the launcher. Indeed, the development trials over the next few years must be described as one long struggle. Progress was slow: there were successes, but they were interspersed with many setbacks. Four attempts at beam-riding were made in the latter part of 1956. Three failed owing to missile faults, but in November the first completely successful flight was achieved, when the missile rode the radar beam satisfactorily for 28 seconds. Two other trials using liquid propellant vehicles both caught fire in flight. This spelt the end of liquid propulsion for Seaslug. The few remaining samples were used in experiments but from 1957 the solid sustainer was established as standard, initially employing a type called Foxhound. Eighteen of these new prototype missiles were launched during the year, inauspiciously at first with many failures. There was a firing pause in the middle of the year while the GMY(1) radar was being completely overhauled, after which the responsibility for its maintenance and operation passed from the Australian Navy to GEC.[32] A British mission arrived at WRE in October to discuss the future program, which may well have supplied moral encouragement because the year ended with a series of six successful flight trials, two of which were efficient beam-riders.

More work was in progress at the Range E launch area through most of 1958 in installing the Girdleness Test Equipment, an assembly of automatic pre-launch test apparatus destined for use on the Royal Navy vessels (initially HMS *Girdleness*) armed with

Seaslug weapons. It was ready for proving checks by October, when it was noted that the launcher test post had started to look like the inside of a battleship! During the same period the trials program continued. The first Seaslug firing in Australia against a target aircraft took place in January, and was unfortunately a failure; but a successful interception was achieved a month later. In the course of 1959 half the Seaslugs fired were failures, suffering loss of either guidance or control which sometimes detached wings or caused break-up in flight. However, the continuing development flights were generally much more successful. They investigated the early flight gathering into the radar beam, especially missile control during the boost phase; take-off from a very short 'zero length' launcher, for which smaller wings were fitted; the operation of alternative proximity fuzes; and ways of recovering the spent missile fairly intact. This research program continued over the last three years of development trials and was aimed largely at the design of an improved Seaslug MK 2. The many firings of Seaslugs against targets were a regular feature of Woomera's work from 1959 to late in 1961, and the success rate rose at last to 80 per cent. This was a rather better result than was achieved in the acceptance trials which were then in progress at Aberporth and on HMS *Girdleness*. (Nevertheless, Aberporth reported in August 1960 that thirteen target aircraft had been destroyed in twenty-one firings, which was really too much of a good thing; and avoiding action would be taken to reduce the excessive losses.[33] The Seaslug Mk 1 development trials were completed at Woomera and the program closed in September 1961. By this time the Mk 2 trials were ready to begin.

The Seaslug Mk 2 project had been proposed to WRE by a British mission in October 1960.[34] Its performance was designed to be at least 20 per cent better than its predecessor's. It was to have greatly increased lethality against fast, low aircraft and an operating range of 36 kilometres at 65 000 feet. Moreover, it had new design features to give it an additional capability as an anti-ship weapon. From the outside the new Seaslug looked much like the old, apart from being slightly longer and having reshaped wings. But inside, the propulsion, guidance and fuzing were all drastically changed. The four Gosling boosts and the Deerhound sustainer motor were more powerful. Alternative warheads were now available, although the standard one was still the expanding steel hoop described earlier, and three independent fuze systems were fitted. One was a proximity fuze for aircraft targets, which operated when it detected any infra-red radiation within a radius of 60 metres. This was backed up by an impact fuze which was particularly effective against ships. Thirdly, Seaslug's warhead could be detonated by direct command from the controlling radar when it closed on the target.

The beam-riding guidance system was more sophisticated than hitherto. The GMY(1) ground radar transmitted three distinct beams, one to lock on to the target and follow it automatically, another extending over a wider angle to acquire the missile soon after launch, and the third to guide and control the missile in flight. The Seaslug's trajectory could be controlled in various ways according to the nature of the target; for example, in the case of very low aircraft the guidance beam would be elevated to avoid surface reflections and the missile then commanded to dive upon the target at the critical moment. A similar approach called 'up and over' applied to ship targets at ranges out to 36 kilometres. In this case the missile was flown to a high altitude to take advantage of the reduced air drag before being commanded to dive. These commands and other instructions such as arming and detonating the warhead were sent by coded pulses in the guidance beam.[35]

Seaslug Mk 2 was a technically ambitious project and it was recognised from the start that the development program would be a taxing one. In the event it required three years of effort at Woomera from September 1961 until the end of 1964. The beam-riding method of guidance had one big advantage: apart from the fuze, and in some cases the warhead trials, most of the missile systems could be tested without a target. For the earlier trials, Seaslug Mk 1 airframes were used, fitted with the Mk 2 components which were under test. The results were promising and augured well for the next stage of the program. But in 1962 when the complete new missile with its higher power motors came under test, there was a long series of failures: of eighteen Seaslugs fired, six broke up at separation of the boosts or lost their wings in flight; and the boost motor venturi were being damaged by the intense flame. To cure these problems the wings and their mountings were strengthened and the fierce rolling of the missile, considered to be the root cause, was controlled to give a gentler motion. The boost venturi were reinforced with Durestos, a refractory material. By mid-1963 the problems appeared to be solved, for there were no more failures that year. The remainder of the development program was mainly concerned with fuze and warhead trials and with test flights over the high altitude trajectories for which the Mk 2 was designed.

Target aircraft were employed in a number of trials, one of them being neatly sliced in two by the expanding steel hoop.

The Seaslug Mk 2 acceptance program was a relatively short one as far as the joint project was concerned. Most of the trials were carried out at Aberporth, leaving only four warhead firings to Woomera between April and October 1965. In three of these the target aircraft, a Canberra and two Meteors, were destroyed. The single unsuccessful firing was due to a control system fault, causing the missile to destroy itself eight seconds after launching.

Seaslug trials at Woomera now ceased for some years. The Royal Navy now had its much desired guided weapon system which was installed in HMS *Devonshire* and several other County Class destroyers. But during some years of use another problem appeared. At the JPPAC meeting in September 1970 the British members requested a further series of development trials at Woomera. Seaslugs fired in service use had been breaking up in the air around the time when the boosts separated.[36] The hypothetical cause was the slightly variable burning time of the four boost motors. Each motor came detached as soon as its thrust ceased, and as the four detachments did not happen simultaneously each one imposed a brief but violent asymmetrical force on the missile. The new trials examined this untoward effect, and also tested a new type of proximity fuze working on a capacitative principle instead of detecting infra-red radiation.

The Separation Improvement program began in September 1971 using missiles specially instrumented with stress gauges to measure the force on the structure and high speed cameras to photograph the separation sequence. The total duration of the effect was less than 2 seconds, so the task was not easy.[37] In an attempt to expose the problem, six Seaslugs flew with boosts attached whose burning time varied intentionally from 3.1 to 3.3 seconds. The missiles failed to break up, although the gauges did record excess stress at the rear joint of the motor. On this evidence the boost release system was altered so that the motors detached simultaneously at an optimum moment.[38] After the work finished in November 1972 the Seaslug launcher at Woomera was left intact but not maintained. It was never used again.

GROUND STRIKE WEAPONS

In the mid-1950s two large new guided weapons began their developmental careers, under the names of Blue Water and Blue Steel. Both had the same objective: the bombardment of enemy positions up to 300 kilometres away from the point of launch, and both were intended to carry nuclear warheads. Otherwise they were entirely different. Blue Water was a ground-to-ground artillery rocket for the Army, whereas Blue Steel was a large propelled bomb to be carried and launched by Britain's V-bombers. The two projects coexisted for six years including a period when both were under trial at Woomera, but neither had a long career in service. Like the majority of projects they became zero factors in the rapidly changing military equation, and fell victim to the endless revisions of British defence policy.

Blue Water started life in 1956, when Sir Steuart Mitchell, the Controller of Guided Weapons and Electronics, outlined the concept during a visit to Australia. This new tactical weapon for the Army was a large solid propellant rocket with inertial guidance, and it would require development flight trials over a range of 48 kilometres or more. The firm of English Electric was already doing a feasibility study for the project under the name of Red Rose, intending to start full development in 1958. Operational mobility was the keynote of the military requirement: the missile with its launcher had to be readily transportable by air and land to remote sites, and have a quick launch reaction time.[39] The resulting design was for a rocket 7.6 metres tall with mid-section wings and large tail fins. It was launched almost vertically into its preset trajectory from a modified army vehicle.

Development proceeded rapidly with preliminary test vehicle launchings at Aberporth and Woomera. Small scale flight models, three-eighths of the full size, were used to determine the aerodynamic performance, and thirteen were successfully fired at Woomera between late 1958 and early 1959. Over the next three years English Electric concentrated on producing a full scale version, including two fully guided prototypes that were launched from Aberporth and performed well. Simultaneously Woomera was preparing for the development and evaluation programs of 35 firings. Blue Water called for complex and expensive facilities, including three fully instrumented impact zones at points from 19 kilometres to 115 kilometres down- range. These were being created in mid-1962 in the expectation that development trials would start in the following March; instead, in August 1962, following ministerial changes in London, Blue Water was suddenly cancelled.[40]

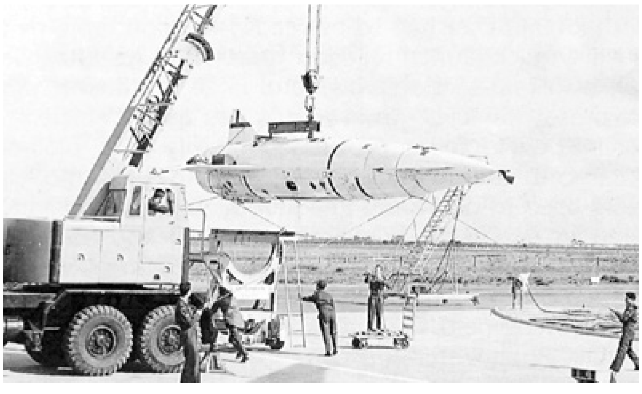
In retrospect the cancellation was not entirely unexpected. For some time unease had been growing about deploying tactical nuclear weapons, for the obvious reason that the proliferation of small battlefield nuclear weapons multiplies the risk of a limited conflict escalating into a full scale strategic nuclear exchange. This whole matter was extremely sensitive within the British government and within NATO, and the public statement of August 1962 was both circumspect and tortuously phrased:

> In view of the increasing numbers and yield of tactical nuclear weapons which are and will in due course be available to NATO, the Government does not consider it justifiable to continue the development of Blue Water as a tactical nuclear weapon for the support of troops in the field which is not planned for use in other theatres.[41]

English Electric took the cancellation hard. The firm's historian calls it a cruel blow. The company had to sack a thousand employees and close its Luton factory, and the effects on its organisation and policy persisted for years afterwards.[42]

A much more ambitious and long lasting project was Blue Steel. This was a supersonic cruise missile, a descendant of the V1 and the Menace 'horizontal flying propulsive duct' (never more than a paper concept), which had figured so prominently in the early plans for Woomera. By the mid-1950s two British firms were actively developing a cruise missile. One was Vickers-Armstrong, working on Dr Barnes Wallis's Swallow aircraft; the other was A. V. Roe (AVRO), with what became Blue Steel. In 1954 the Air Staff issued an operational requirement for a propelled nuclear bomb capable of being launched in any weather from a V-bomber flying well clear of ground defences. Both weapons were accepted by CUKAC as joint project tasks, but Swallow quickly disappeared from view. The AVRO proposal was accepted and a development contract was awarded the company in March 1956.[43]

The shape of Blue Steel was largely dictated by the bulkiness of its nuclear warhead. Still, it looked graceful enough with its sleek cylindrical body of stainless steel 10.7 metres long, tapering down from a maximum width of 1.28 metres to a pointed nose. The main-plane wings were delta-shaped, nearly 4 metres in span, mounted close to the rear together with a pair of vertical stabiliser fins. The 'canard' configuration meant that there was no tailplane; instead a small fore-plane near the nose controlled the pitch angle and, together with ailerons on the rear wings, controlled the flight direction by the 'twist and steer' method. The engine was at first Armstrong-Siddeley's Spectre, soon replaced by their more powerful Stentor: both burnt the liquid propellants kerosene and HTP. The Stentor engine had two combustion chambers of different sizes mounted one above the other. Operating together from launch with a combined thrust of almost 12 tonnes weight, they acted as a booster accelerating Blue Steel to a supersonic speed approaching Mach 2.5 at 75 000 feet. From this point the smaller chamber alone served as a sustainer, maintaining cruising speed to the target.[44] The guidance and control system was produced by Elliott, the British electronics firm. Its heart was the inertial navigator which constantly measured the location of the missile in space and compared it with the programmed target position. (Data from the aircraft navigation were fed to the Blue Steel 'brain' right up to the moment of launch to fix the target position.) After launch, corrections to the flight path were passed via a computer to the autopilot, which steered the missile as well as keeping it stable in flight. A Blue Steel in flight was immune to all countermeasures short of direct attack.



Right: Dr Barnes Wallis with a model of his proposed Swallow swing-wing aircraft. (British Aerospace)

Far *right*: Lifting a Blue Steel from its transporter before loading it into a Victor bomber at Edinburgh.

The basis for trials planning and facility preparation was worked out during three visiting British missions in 1956-57. The object of the preliminary trials was to explore likely problems connected with aerodynamic stability, control, and kinetic heating effects at supersonic speed. Scale models would suffice for these investigations just as in the case of Blue Water. However, since Blue Steel was an air-launched missile its trials had the complicating factor of the carrier aircraft. In fact, all three types of the V-bomber force took part at various times. They were located at Edinburgh Airfield, which with WRE became the base for preparing and loading the missiles before flying to Woomera. This work was done under extreme security. The transporter parking bay at WRE was screened by a fence 5 metres high, which was still standing thirty years later.

The flight program was ready to begin in July 1957 with the arrival of the trials team, the Valiant carrier aircraft and the first of the two-fifths scale models. This was a 'cold' missile with fixed controls and no engine, intended for use as a practice exercise. The trial was duly carried out in August. Subsequent flights were originally planned to continue at one per month, but it was February 1958 before the next scale model was launched. This time the missile was more complete; it had a solid fuel motor with a burning time of 25 seconds which would propel the model more than 60 kilometres down-range from its release point over Range E. It carried two telemetry senders, and the Valiant was fitted with bomb bay and wing tip cameras to photograph the launch. The Range had provided corresponding ground instrumentation for receiving the telemetered data, plotting the trajectories of aircraft and missile and photographing their behaviour. This was the first flight in Australia of a motored Blue Steel (albeit only a scaled down version) and its success was encouraging: the propulsion and controls worked well and the missile flew smoothly to the recovery zone, its final descent slowed by a parachute.

The following few months were occupied with carry-over trials to check the instrumentation and launching procedures again. The next scale model was launched in May with rather dismal results: neither the motor nor the autopilot operated correctly and the missile crashed before the parachute opened. However, towards the end of the year four more models were launched, two of which performed well. Of the remainder, one suffered an impediment at launch which caused it to dive steeply, while in the other a timing failure prevented motor ignition. (Nevertheless it glided gently for over five minutes under the control of its autopilot to a landing 50 kilometres down-range.) In 1959, eight missiles were launched to complete the planned series of fifteen scale models. The results in general were satisfactory with only two outright failures caused by the solid fuel motor and the control system. Trials of the full size Blue Steel, already more than a year behind schedule, could now begin. By mid-1960 the service unit 4 JSTU had arrived, ready to take part with AVRO in the combined development-acceptance program of sixty launchings. With all the planning underway, the remainder of 1960 saw no trials except for two flights, unpowered and unguided, to prove the safety and tracking systems.

Meanwhile WRE had been working on the ground instrumentation network. The main impact zone was a circle 37 kilometres across, the closest point of whose perimeter lay a few kilometres to the south of the Mirikata tracking station. This allowed a flight of some 200 kilometres down-range from the release point above Range E. Depending on the aircraft altitude at launch, the missile would first soar to 80 000 feet and then continue on a plateau before diving steeply to impact, its long trajectory monitored by the FPS-16 radars at Red Lake and Mirikata supported by a succession of other Range radars types AA 3 and 4 Mk 7. Additionally, the Missile Tracking System and two new kinetheodolite posts first put in for Bloodhound Mk 2 covered the cruise period, with a long focal length camera near the impact zone to photograph the final dive to earth.[45] Blue Steel carried four telemetry senders to transmit data to stations at Mirikata, Mt Eba and the rangehead. In some later firings two of the senders were replaced by a special type provided by the Atomic Weapons Research Establishment to check the operation of an 'explosive test unit', which simulated the triggering of the future warhead. They required receiving stations within the impact area, remotely operated by a new control centre near McDouall Peak. Complete Blue Steels started to fly in 1961 with poor results at first but with some improvement in the next year until about one flight in two was successful. It was no better than that because of a new problem with the auxiliary power unit, a small HTP-driven turbine which supplied hydraulic power to the alternators and control surfaces. It failed repeatedly and was alone responsible for at least eight unsuccessful flights.

A Victor carrying a Blue Steel takes off.

The future of Blue Steel had been uncertain ever since 1960 when the big ground-to-ground ballistic missile Blue Streak was cancelled. In one view Blue Steel was even more urgent than before, to give the British armoury at least one nuclear- tipped missile; but in another view the fact that Blue Streak was supposedly being replaced by the advanced American air-to-ground Skybolt rendered Blue Steel superfluous. To complicate matters, the future of Skybolt was itself uncertain. Moreover, the Soviet Union's ground defences had been much improved. Blue Steel needed more range and the capacity to be launched and to fly at low altitude to avoid radar detection. The net result was that the effort which had been allocated to a Blue Steel Mk 2 was absorbed by the design problems of modifying the Mk 1.[46] In the meantime, in September 1962 Mk 1 Blue Steels were fitted to the Vulcans of the RAF's 617 'Dam Busters' Squadron and afterwards to the aircraft of four other squadrons.

These factors disturbed the Woomera trials program greatly, though it continued through 1963 with launchings from Vulcan and Victor aircraft until the completion of the development trials in March 1964. They were immediately followed by a short acceptance program conducted by 4 JSTU with representatives of the British Aeroplane and Armament Experimental Establishment at Boscombe Down. Eleven missiles were launched, most of them at low level, to complete the program with a final successful flight in October 1964.[47] By the following January the closure of the Blue Steel program was well in hand. Even so, its resumption was for a time not completely ruled out. WRE issued an agreed closing down specification which allowed for second thoughts:

> The Ministry of Aviation is considering the need for further Blue Steel trials. Until a decision has been made certain buildings presently allocated to the project will be preserved. The situation will be reviewed at intervals of six months and the buildings will only be held available while MOA certifies that there is a reasonable possibility of further trials taking place. The period of preservation is not expected to extend beyond the end of 1965.[48]

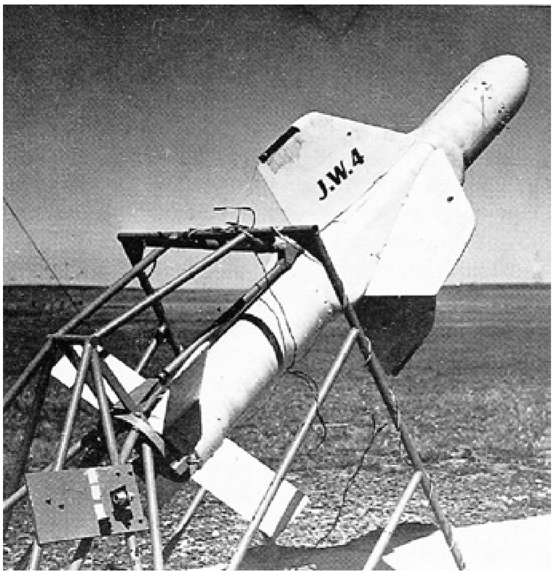
But Blue Steel was not reprieved. The RAF gradually phased it out of service and with its demise British aircraft ceased altogether to carry atomic weapons. The responsibility for the British nuclear deterrent was transferred to the Royal Navy with its Polaris submarine fleet.

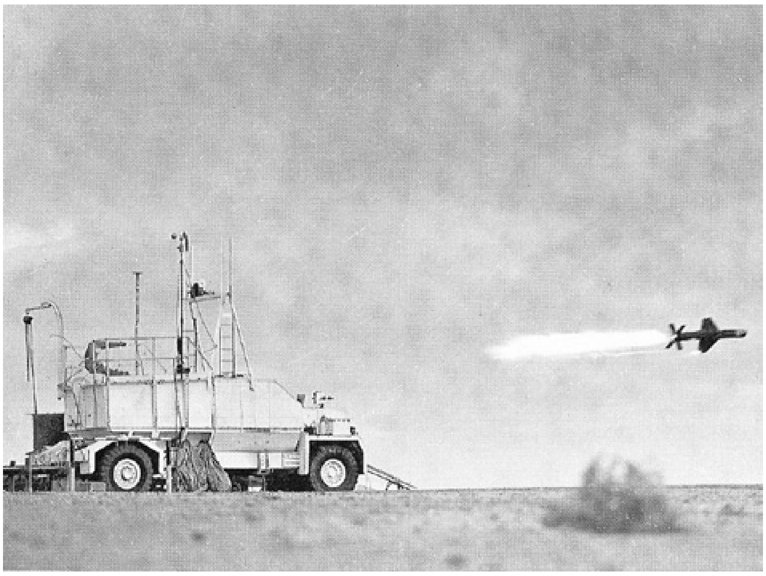
AUSTRALIAN WEAPONS

Most of the guided missiles tested at Woomera under the joint project were British in origin. A few, however, were indigenously Australian and, of these, two in particular were so successful that eventually they became service weapons. These two had nothing in common, either in purpose or in configuration. One was a short range anti-tank weapon named Malkara ('shield'), intended for infantry use on the battlefield. The other was Ikara ('throwing stick')—a long range missile for attacking submarines, initially developed for the Australian Navy but later taken by the British Navy too. Work on Malkara and Ikara lasted for many years at Woomera and elsewhere.

In a previous chapter we have described LRWE's involvement over the period 1950-55 with Project E, a lightweight anti-tank guided missile. The British Army was interested in acquiring a similar weapon and after consultations the Department of Supply agreed to develop and manufacture a weapon in Australia for British use. The result, Malkara, operated on similar principles to Project E, but carried a much larger warhead. MoS had insisted that it should be increased from 5.5 kilograms to a massive 25 kilograms. Malkara was therefore a much bigger and heavier weapon, not fired from the shoulder but from an easily mobile launcher. It held no appeal for the Australian Army, where a powerful faction saw little use for missiles in jungle warfare and preferred to retain anti-tank artillery.

Malkara was a short stubby rocket 1.8 metres long and 20 centimetres in diameter, weighing 98 kilograms. It had the conventional arrangement of cruciform mid-section wings and tail fins, and was propelled by an integral solid fuel motor cleverly designed by WRE's Propulsion Division with two programmed levels of thrust so that it acted as both boost and sustainer. A pilot steered it along his line of sight to the target using a joystick to transmit impulses down a thin cable paid out as it flew. In the missile the amplified signals caused it to pitch or yaw by moving the lateral or the vertical pair of wings. Any tendency to roll was detected by a gyroscope which corrected it automatically by producing an opposing wing movement. The early versions of Malkara had an effective attack range between 450 and



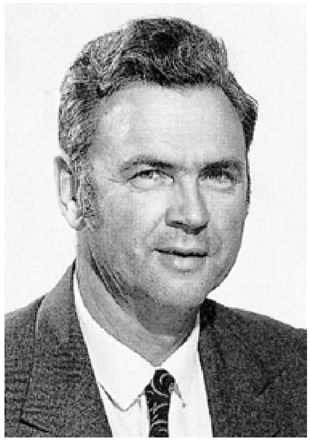


1800 metres, with a flight time of about 15 seconds. Later versions had twice this range. Unlike Project E, the pilot was not limited to staying at the point of launch, although this was the usual position if the equipment was in an army vehicle. He could position himself up to 180 metres away in any direction except, presumably, in front.

Above left: An experimental Australian Malkara anti-tank weapon during early development trials in mid-1955.

Above: Launching Malkara from its mobile vehicle, in which sat the pilot who steered it to its target.

Malkara was developed by the Government Aircraft Factory (GAF) in collaboration with the Aeronautical Research Laboratories (ARL) in Melbourne, with the Propulsion Research Laboratory at Salisbury developing the rocket motors and LRWE looking after the Woomera trials. The missiles were manufactured by GAF. The key person in the whole Malkara project was J. M. (Murray) Evans, a research scientist at ARL, who was seconded to GAF as chief designer, project officer and the most frequent pilot of Malkara.



J. M. (Murray) Evans, who took a leading part in developing Malkara and the later Ikara.

Malkara trials at Woomera began in May 1954 with a few experimental firings, and continued through the following year when twenty-eight missiles were launched. Most of the firings were to test the motor performance, the roll stability, and the reliability of the cable dispensing system. In November 1955 the first attempts were made to guide the missiles to a fixed target 900 metres away. Six were fired and two hit the target, but the others went widely astray soon after launch. Various types of solid propellant motor were being tested at this time, and the problem was solved by a redesigned efflux nozzle to ensure that the motor thrust was more accurately aligned to the missile axis. Progress in 1956 was rapid, averaging more than five firings per month with a high percentage of hits on fixed and moving targets at ranges up to 1800 metres.

The Ministry of Supply now sent a mission to discover whether Malkara met the Army's requirement. After a round tour of the various establishments they attended the firing trials in progress at Woomera. One of the party, Brigadier Gwynne Lewis recalls:

> A key member of this mission was Lt Col Eric Offord DSO . . . who in World War II had been blinded in the right eye and lost the use of his right hand, yet was extremely keen to fire Malkara. After a short period of training he had learned to operate the joystick control with his left hand and apply his good left eye to the optical sight designed for the right eye. Fired from a range of 1000 yards, his missile hit the ground about twenty yards short of the target, then to the cheers of the spectators ricocheted straight through the centre of the bulls-eye, wrecking a recording camera as it did so.[49]

The same successful firing rate continued through 1957, although some difficulties were occurring with smoke emission from the motor, which tended to obscure the target. Further work on the propellant composition extended into the early part of 1958 and there were fewer firings. However they were all successful, including one which smashed through the 13 millimetre steel boiler plate of a simulated tank from 1400 metres. By the end of the year the development program was completed and arrangements were in hand for British acceptance tests. With Malkara a success, the Australians started thinking about a lighter version with better range called Toolondoo, also for the British market. After some experiments in 1958 Toolondoo dwindled away to a design study and vanished by the end of 1959.[50]

Meanwhile the first 150 Malkaras had arrived in Britain and the Army, with help from an Australian team led by Evans, was trying them out at Kirkcudbright in Scotland. Some problems still existed with the propellant smoke's obscuring the view, but the trials were so successful (nine missiles out of ten were able to hit even a moving target) that the War Office ordered another 1000 Malkaras in August 1959 to equip the Royal Armoured Corps. Production was scheduled to begin within nine months, with Australia supplying the missiles and their associated equipment and Britain the warheads and launcher vehicles. The first batch of about 230 was to be of the tested Mk 1 type, but it was agreed that the remainder would be a Mk 1A version, whose improvements included a longer range of 3500 metres.

The factory-built Mk 1 missiles were successfully proof-tested at Woomera in September 1960 and deliveries to Britain commenced. The Mk 1A type was then still under development, although preliminary test vehicles had already been flown to well beyond the specified range. By early 1961 its basic design was agreed and production trials were ready to begin.[51] However, the planning was over-optimistic; production delays occurred because of problems with the system which affected its service use. The development trials took so long that it was not until 1964 that production was virtually complete. By that time, most of the Malkara servicing was being handled by a new anti-tank division of the British Aircraft Corporation at Stevenage. To say that the Army took the Malkaras more out of a sense of obligation than enthusiasm may be an exaggeration, but certainly it ordered no more of them after 1959-61. In 1959 Fairey had started a very similar weapon called Swingfire. Swingfire had a long development but the Army eventually adopted it in about 1968. Since by then it also had a personal anti-tank weapon in the Vickers Vigilant, the British Army ended up, by accident or design, with purely domestic versions of both Malkara and Project E. The Australian Army had neither. The whole episode cannot be viewed as one of the triumphs of the joint project.[52]

The Ikara project was a shipborne anti-submarine weapon for use at long range. Ships at sea detect submarines by sonar, which transmits and detects sound pulses through water and is consequently highly susceptible to aberrations, both natural and otherwise. Nevertheless, under favourable conditions sonar could detect a submarine at 20 kilometres or more—well outside the range of an orthodox torpedo. The idea behind Ikara was to exploit this fact by using a guided missile to fly a torpedo to the target site, releasing it into the sea at the best possible position. The torpedo would then home on to the submarine using its own guidance and propulsion. This concept did not originate in Australia. The French had a weapon called Malafon which was in development three years before Ikara and was virtually identical to it except that the missile was twice the size and had a somewhat shorter range of 13 kilometres.

In 1959 Australia, knowing of Malafon which by then was undergoing its first development trials, decided to develop the idea for its own Navy under the code- name Blue Duck. Within a few months the project organisation had been set up, not without resistance from senior RAN officers, one of whom was heard to ask loudly and rhetorically, 'What bloody nonsense will they think of next?'[53] The co-ordinating design authority was ARL Melbourne, with strong support from WRE where two special divisions and its subcontractor, EMI, were responsible for the missile propulsion and guidance, the shipborne displays and the telemetry. The Government Aircraft Factory made the missile airframes and flight control systems and also provided the project trial teams at Woomera. Thus the entire development was Australian (it took nothing but the bare idea from the French original), although both Britain and the United States were interested onlookers. In fact, the American Defense Department's Advanced Research Projects Agency came up with a grant of £1.7m, an opportune gift as the development cost estimates had just risen by almost that amount.

By the middle of 1960 Ikara existed as a basic design. It had a distinctive shape: 3.4 metres long with horizontal delta-shaped wings 1.5 metres in span and vertical fins at the rear. The body section was ovate, 65 centimetres from top to bottom including a faired-in bay on the underside where the torpedo nestled. It had a composite boost-sustainer solid motor, and was guided in flight by the twist and steer method using movable flaps on the trailing edges of the wings. The torpedo, selected for its light weight, was the American US Mk 44, 2.5 metres long, which homed on the target using active sonar guidance.

Naturally Ikara's specialised function required a guidance system much more complicated than that of the usual guided weapon. It depended on a computer on board the controlling vessel, into which was fed the position of the target obtained either by the ship's sonar or from outside sources such as a support ship or even from a sound-ranging device lowered into the sea from a helicopter. After launch Ikara was tracked by a computer which constantly compared its position with the target's, and issued commands to steer it on course. This demanded a two-way radio link between the parent ship and the missile. Steering commands were transmitted as UHF pulses, to which the missile gave replies on a microwave frequency. These replies, received via highly directional aerials, supplied continuously updated information on Ikara's exact position, so that the computer could continue to adjust the flight path right up to giving the last signal to release the torpedo. Throughout Ikara's flight the gradually closing positions of the missile and the submarine were displayed to a controlling officer, who could override the computer manually if required.

A project as complex and as unfamiliar as Ikara obviously required long development to prove each element of the system in successive stages. To begin with, scale models of the missile, three-fifths of its full size, were employed to test its flight stability and steering. Some models even carried a scale model dummy torpedo which could be released on command. These trials began in February 1961. The flights were rather brief as the solid propellant motor consisted only of a short-burning boost, giving a speed of 150 metres per second to an impact point about 3 kilometres down-range. Flight control was either pre-programmed or commanded from the ground over a wire link in the style of Malkara. Then by the end of the year the first of the full size prototypes was ready for firing. It still retained the boost- only motor so again its flight was short. However, during 1962 a combined boost-sustainer motor named Murawa was used, giving a higher flight speed and the full range. Control was by a radio link. At the same time the two-way radio guidance system was being developed, employing a DC-3 aircraft which carried the equipment on various courses and used it as a flight direction indicator to reach pre-arranged target positions.[54]

By 1963 the components were coming together into a whole. In April, four full standard missiles were launched at Woomera on a guided trajectory to fixed aiming points, ejecting a torpedo which parachuted within pick-up range of the hypothetical target. Two were completely successful but the others failed because of minor internal defects. The Australian Navy was also starting sea trials off the Queensland coast at Bundaberg, using fixed-wing launchings from HMAS *Stuart* to establish the firing procedure and then continuing with guided flights. A number of failures indicated problems with reliability, but otherwise the system proved to be operationally sound. In early 1964 two sea trials used actively guided torpedos which successfully homed on to their targets.[55]

British interest in the project was now confirmed. A mission was sent to Australia in December 1964 to discuss arrangements for a Royal Navy version of Ikara, culminating in a

Left: A prototype Ikara on its launcher at Range E in 1962.

Below: Preparing a Murawa boost-sustainer motor for a static firing at Salisbury in 1974.

formal agreement in March 1965 for its development. The British version was modified in various ways. It had to fit Type 82 guided missile destroyers of the Royal Navy, and it had to work when British sonars located the target. It was also made suitable for four alternative payloads, one of which was a large high explosive bomb. The RN Ikara trials program was scheduled to begin in April 1967 at Woomera, initially employing Canberra and DC-3 aircraft for tests of payload deployment and missile guidance and tracking. A development launching program of twenty-one missiles would then continue to the end of 1968.[56]

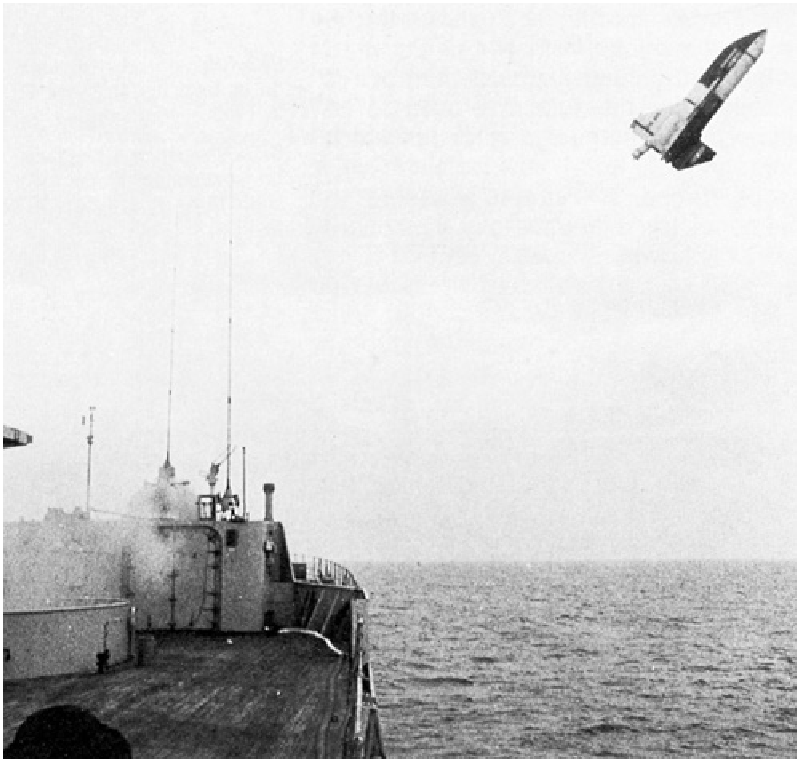
Australia also had plans for improving its Ikara, including giving it the option of an additional type of payload. In addition, a new launcher facility called Mattina ('double-pointed club') had to be tested. This was a safety device which harmlessly but dramatically ejected faulty missiles from the launcher. Mattina was a rocket motor which strapped on to the failed Ikara and then, with a momentary thrust, tossed it well clear of the ship into the sea.[57]

The RN and RAN development programs went forward concurrently, but several changes of design delayed the start of the Woomera trials. In the meantime the RAN conducted a joint sea trial with the US Navy off Hawaii early in 1966, during which two Ikaras (evidently using unarmed torpedoes) hit submarines travelling submerged at 9 knots. However, the Woomera programs were under way in 1968 and were virtually completed by the end of the year. The production phase of the RN Ikara was authorised in November, aiming for a delivery of 100 missiles to Britain by September 1970. The modified RAN Ikara was scheduled for Australian Navy service in 1969. The production of the British Ikara had some problems, particularly with the solid propellant used in the Murawa motor which deteriorated unless kept cool.[58] But by the end of 1971 a complete Ikara system had been installed in the navy destroyer HMS *Bristol*, and all the shipborne gear for two other vessels had been delivered. Production was now smoothly in progress and was maintained by subsequent orders from Britain for a continuing supply of missiles and equipment.

Ikara long continued to be a success story. Brazil commissioned and bought a version called Branik to equip four ships of its navy, and in 1977 the thousandth missile came off the production line and was delivered to the RAN. Ikara has undergone continual technological improvement, and five years after the end of the joint project the navies of both partners still had it in full operational service and upgraded marks were appearing regularly.

Below right: RAN Ikara in its shipboard launcher.

Below: An RN Ikara launch from HMS *Bristol* in 1970 (MOD).



NEW WEAPONS FOR THE NAVY

In the 1960s, while Seaslug was in the throes of its trials program, two more advanced shipborne missiles were in development to meet the future requirements of the British Navy. The first to appear was Sea Dart, a weapon with sufficient range to give area defence against both hostile aircraft and hostile ships. Then, towards the end of the decade, Seawolf followed. This was a short range missile with a very fast reaction time, capable of intercepting not only attacking aircraft but even supersonic guided missiles.

Sea Dart, accepted under the joint project in 1963 under the original code- name CF299, was developed by a large consortium of five (later eight) British companies including Hawker de Havilland, GEC and Sperry Gyroscope. Externally it looked conventional enough with its four highly swept back cruciform wings and its movable tail fins for control. At the rear was mounted a solid boost motor, making the missile 4 to 5 metres long at launch. But internally Sea Dart was very different. The body, 42 centimetres in diameter, consisted of two concentric tubes. In the inner thick walled tube was a Rolls-Royce ram jet engine, while in the annular space around it was neatly packaged all the electronics and the tanks of liquid fuel. It was an elegant way of reducing the overall length. Sea Dart used semi-active homing, and it had four receiving aerials mounted on the nose around a pod suspended centrally within the engine air intake, containing the homing unit and the warhead. Its powerful boost motor took it up to twice the speed of sound within 3 seconds of launch; then the boost jettisoned and the ram jet sustainer took over, burning for another 30 seconds. The usual role of Sea Dart was to protect its ship against very low flying aircraft, which was a role not filled at the time by any other weapon.

Sea Dart's development trials were very carefully planned as a graduated sequence of at least ten test vehicles—JA, JB and so on—to prove each element in turn from the boost motor to the fully homing missile. Unfortunately this smooth progression was badly disrupted in the first year by one technical problem after another. The Woomera trials began in 1965 but were marred by many failures which took until the middle of the following year to resolve. After that, development went more or less according to plan until completion at the end of 1968. The following acceptance trials also suffered from delays and continued slowly until March 1973, with the evaluation program finishing exactly a year later.

A Sea Dart missile blasts off from its Range E launcher. Signs warn of radiation from the illumination radar.

Sea Dart was adopted for Royal Navy service at this time, being first installed in a destroyer, HMS *Bristol*. Yet the trials results could not perhaps have inspired complete confidence in its performance. In September 1974 a planning mission arrived to discuss two further short programs of trials.[59] The first, called Reliability Improvement Trials, involved six missiles, all with warheads. The second was to test improvements to Sea Dart performance against sea-skimming attack missiles. The trials were accepted and, beginning in September 1975, proceeded concurrently to a satisfactory conclusion early in the following year. Sea Dart did not return to Woomera, but there was an epilogue. In February 1979 a British mission came to Australia to ask about trials of a Mk 2 version, for which land impact and recovery were particularly required. A five year program starting in 1982 was proposed.[60] But it was too late. The run-down of Woomera was already far advanced, and nothing more was heard of Sea Dart as far as the joint project was concerned.

The origins of Seawolf went as far back as 1963 when the British Aircraft Corporation started to look at a system called Confessor. Governmental support came in 1966 with a contract for a more detailed design, followed two years later with a development contract placed on a consortium whose members were BAC, Marconi, Ferranti, Vickers and EMI. As usual Aberporth handled the first trials, but Seawolf had novel features which expressly required a long overland range. It was to function in part as an anti-missile missile, and to test its mettle it had to be fired against a small supersonic rocket target. Here WRE had to provide a unique facility.

Unlike its naval predecessors Seawolf was a short range missile only 2 metres long with delta-shaped fixed cruciform wings and movable tail fins. Propulsion was by a solid propellant boost motor. Seawolf had no sustainer and it became an unpowered dart when the boost burnt out, but its initial speed was enough to maintain supersonic flight over its full range. (It had a short range as Seawolf was primarily a defensive weapon against approaching targets.) The warhead was the fragmentation type, with an explosive charge triggered by a radar proximity fuze. Seawolf had no internal homing mechanism: it was guided by radio commands issuing from equipment at the launcher. This line-of-sight principle, an automated development of the optical guidance used for Malkara and the early Rapier, was highly refined and very fast acting. At launch the shipborne radar tracked both target and Seawolf, the latter carrying a distinctive beacon. If the missile started to deviate from a direct line to the target, a computer calculated and transmitted corrections within milliseconds.[61] If the tracking radar was following a ship or a missile coming in low it could be confused by echoes off the sea, so Seawolf had a supplementary television guidance system.

By September 1969, when a second planning mission visited Australia, WRE had made good progress with their supersonic target design.[62] The plan was to take a simple research rocket called Petrel and modify it slightly. The resulting missile, produced together with its launcher by Bristol Aerojets in Britain, had two propulsion stages. The boosts were four small solid motors called Chick 2As. They were only 50 centimetres long, but acting together gave a thrust of 1800 kilograms weight for a fifth of a second. The second stage,

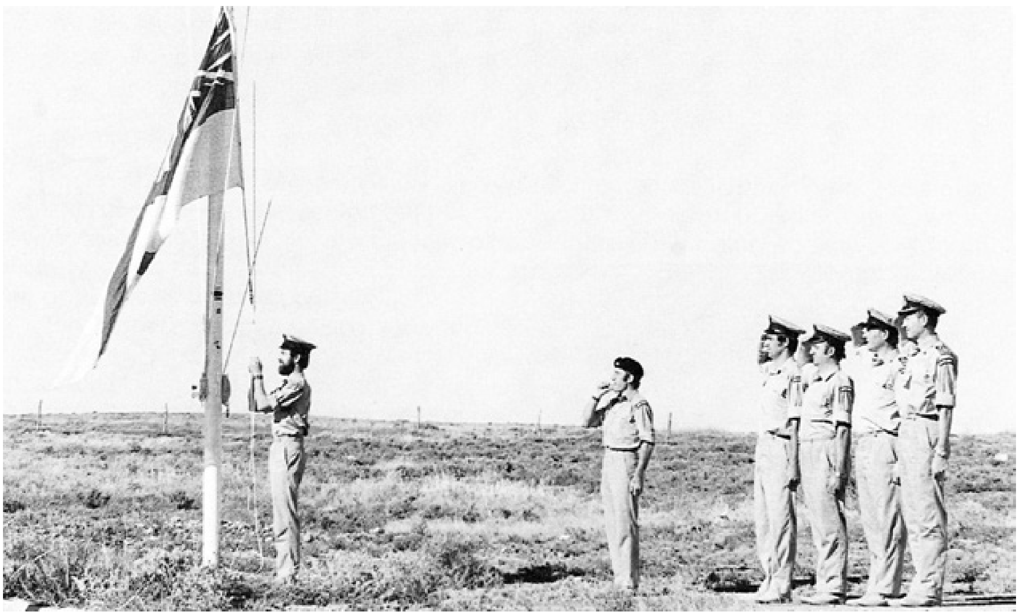
The RN unit 25 ISTU at Woomera, with a Seawolf missile in front.

a large solid fuel Lapwing motor, was 1.9 metres long and supplied thrust for about 40 seconds. Petrel was an unguided missile, aimed like a gun and fired through a 10 metre long tube. All five of its motors were ignited simultaneously, with the Chicks burning out before the rocket had even left the tube. Petrel's trajectory could be altered simply by changing the elevation of the tube, but typically it could reach a height of 5700 feet at Mach 2.3 and land 24 kilometres from the launch site. One apparently alarming feature was the launching direction, for Petrel was fired from down-range back towards the rangehead. As it approached at supersonic speed, the Seawolf radar at Launcher Area 9 was supposed to lock on to it and an intercepting missile be fired. Naturally the possible limits of its zone of impact if Seawolf failed were meticulously calculated, and at Area 9 (5 kilometres down-range and slightly off the Range centre line) a large underground control room protected the staff and equipment.

The first Seawolf trials began at Aberporth in early 1970 while WRE was simultaneously flight testing the Petrel target at Woomera. Unfortunately the Woomera development trials, due to begin in 1971, were repeatedly postponed for almost two years because of trouble with Seawolf's radar at Aberporth. This delay gave WRE abundant time to complete the Area 9 installations and to carry out more flight tests of Petrel; and once this was proven the system was contracted out to Short Brothers and Harland to relieve WRE's workload. When the radar and television tracking equipment finally did arrive by air at Woomera in March 1972, much of the year was spent preparing it and checking it against a towed Rushton target. The first Seawolf, an experimental television guided missile, was launched in November, followed by a second firing at a low flying Jindivik which failed owing to a control system defect. However, successes came in 1973 with twelve radar guided firings, eight at Petrels and the others at Rushtons or Jindiviks. Nine were completely successful with miss distances as low as 2 metres, while one Petrel was destroyed by a direct hit. The three failures were readily explained: one was caused by an inadvertent triggering of the self-destruct system and two were attributable to the ground equipment.[63] Apart from the missile program, many non-firing trials were conducted against aircraft and Petrel targets to test the radar and television tracking systems.

Nineteen missiles had been allowed for the development trials, but early in 1974 enough information had been gathered and the program moved on to its rearranged evaluation phase. The service team appointed to conduct these trials was 25 JSTU, the first Royal Navy unit seen at Woomera. The main party arrived with their families in July and at once merged enthusiastically into the Woomera scene. That winter was unusually rainy, like several over those years, and with the saltpan of Lake Koolymilka filled with water the Naval team had the opportunity of demonstrating their nautical prowess with their own dinghy. One member recalls:

> After one party we decided to go sailing. Nelson would not have been impressed. Not only did we manage to turn the boat over, but the ensuing rescue and salvage of the crew and craft left much to be desired[64]



The Royal Navy lowers the White Ensign for the last time at the Seawolf launching site.

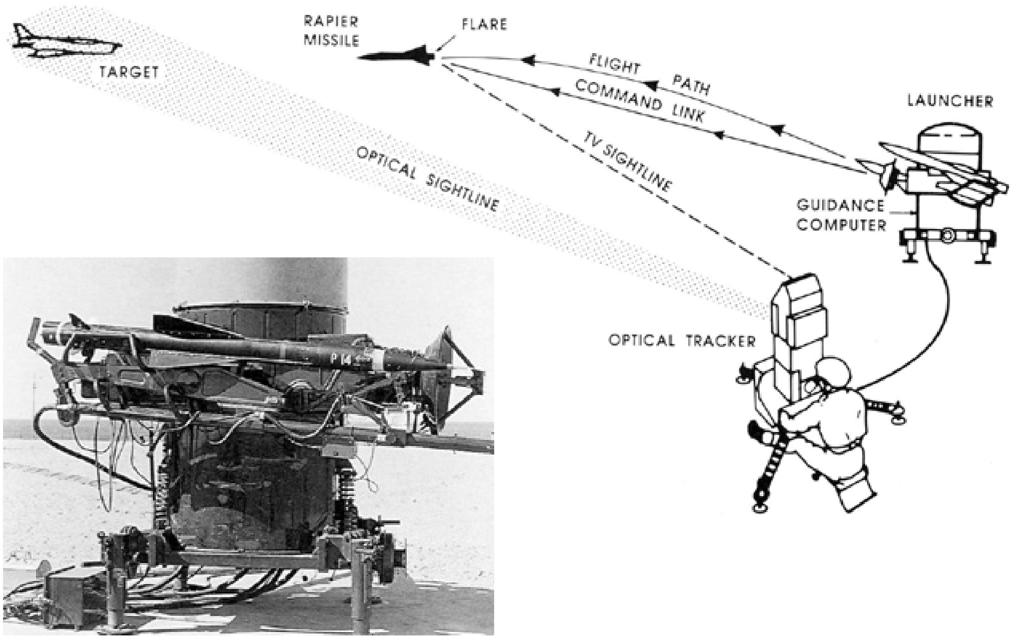
25 JSTU took over the trials work in September 1974, promptly hoisting the White Ensign over Area 9. The evaluation program had two objectives: to let the service team appraise the Seawolf system and report any snags, and to discover the performance limits of Seawolf and validate the modelling work done earlier. Twenty- two Seawolfs were provided for the program, which required satisfactory results from at least twelve different target-engagement conditions out of a proposed list of fourteen.[65] The trials included four salvo firings each of two missiles, plus a number of tracking-only trials. The evaluation program was over by August 1975 and 25 JSTU reluctantly returned home. Most of the ground equipment followed in four special RAF flights and the Petrel target service closed. Seawolf was subsequently installed in the HMS P*enelope* for trials at sea. It entered service in 1979 on RN22 class frigates, and was fired in battle during the Falklands War. Seawolf was developed further afterwards to produce a lightweight version for smaller vessels, but by that time Woomera was no longer available for its trials.

THE ARMY'S RAPIER

Rapier, an anti-aircraft missile system, dated back to 1959 when English Electric did some studies for PT428, which was a mobile, short range, ground-to-air weapon to supplement their Thunderbird. PT428 had only a brief career before being cancelled in 1962 because of competition from a similar American weapon for NATO called Mauler, which was itself cancelled later. However, English Electric, by then absorbed into the British Aircraft Corporation (BAC), continued to work privately on a simpler version of PT428. The outcome was profitable because in March 1964 BAC received a contract to continue development of this version under the name ET316, later renamed Rapier.[66] The intention had been to give PT428 an advanced auto-tracking radar system, but Rapier used simpler optical tracking which relied on the competence of the operator.

Rapier was a highly mobile and self-contained weapon, small enough to fit in a tracked vehicle or on a trailer towed by a Land Rover. It consisted of a rotatable launcher with four missiles, a surveillance radar, a guidance computer and a command transmitter. The manned optical tracker was separate and could be placed at a convenient distance. In use, the radar continuously scanned the sky and interrogated any approaching aircraft for an Identification Friend or Foe (IFF) response. If none was received the operator was alerted and the launcher and tracker swivelled automatically to point at the target. After that it was up to the operator. Using a binocular sighter and a joystick to fix the target in a cross-wire, he chose the right moment to fire a missile. Provided he continued to keep the target tracked, guidance was automatic thereafter: a TV camera in the tracker detected the tail flare on the missile and the computer calculated any necessary corrections and sent commands by

The Rapier tracking system



A lone Rapier missile on the rotatable launcher at Area 9 (1968).

radio.[67] The Rapier missile itself was a 94 kilogram winged needle 2.2 metres long and barely 13 centimetres in diameter. It had small swept-back wings and movable tail fins for control. The motor was a solid combined boost-sustainer type giving it a speed exceeding Mach 2, but the range was short and only useful against aircraft flying below 10 000 feet. The missile was a 'hittile' in that the small warhead exploded on contact.

The components of the Rapier system were built by several British companies in association with BAC, and all the early trials were done at Aberporth. Only the service evaluation program came to Woomera after a mission in February 1966 had confirmed details of the launching site and the Range instrumentation. The service trials unit 21 JSTU arrived in mid-1967 and the Rapier equipment by air in October. 21 JSTU was a particularly diverse team of seventy servicemen from various Army regiments, the RAF regiment and the Australian Army Guided Weapons Trials Unit. They kept a small detachment at Salisbury, but most of them lived at Woomera. The run of wet winters in the outback was just starting at this time and, like the naval unit some years later, the servicemen were able to spend their leisure sailing on Lake Koolymilka.[68]

The trials began in December 1967 with some firings of fixed fin and tape programmed missiles to give experience. The initial trials were not good, with various tracking problems with the missile and ground equipment, and the trouble carried over into the evaluation trials which started in April 1968. For a few months the program reverted to development trials to sort out the problems. Mostly they were technical, but one was human. Some operators could track the target perfectly if that was the limit of the trial, but their accuracy deteriorated markedly under the stress of a live firing. Ron Speight, a psychologist from the Army Personnel Research Establishment at Farnborough, studied the problem and referred his ideas to a British university. The degree of susceptibility to stress can be measured from factors appearing in the urine, and the university called for samples to be quick-frozen after each firing and dispatched air freight for analysis. The resulting cryptic telexes passing between BDRSS at Salisbury and London caused some astonishment in the teleprinter room.[69]

Whatever the reasons, when evaluation resumed in September the situation was transformed with nine successful firings. The operators had to begin turning aside the missile at the last moment to avoid too many target losses. One firing in November was particularly impressive. 21 JSTU was being visited by the Australian Army Board and for that occasion an all-Australian team conducted the trial and did not turn away the missile. The Meteor target was totally destroyed. The evaluation program continued successfully in 1969. An officer of 21 JSTU, Major Fuller, reported:

Major Fred Fuller of 21 JSTU Woomera, 1968.

> Techniques and skills had so improved that two firings a day were sometimes being accomplished. In April, Mirage aircraft from the RAAF flew a series of flyover trials at both subsonic and supersonic speeds. The pilots enjoyed it immensely as they were not normally allowed to fly supersonic below 30 000 feet and we were asking them to do it at 1000 feet. They were not so happy however when they saw the tracking films of the operations. One operator had aligned the cross-wires of his tracker on the pilot and had followed him round during a climbing turn. The pilot thought this was being a little too personal! In May, after the departure of the Mirages, Rapier firings resumed. They continued with varying success through to September and as a grand finale, two warhead rounds were fired that destroyed their targets.[70]

With evaluation completed 21 JSTU withdrew to Salisbury. Their remaining task was to pack up the equipment for shipment to Singapore, where a series of proving trials took place in a humid tropical climate. The legacy of Rapier work at Salisbury was a heavy program of computer modelling, a long and difficult task which took until September 1971.

In January 1972, 21 JSTU returned to Australia but not to Woomera; it was engaged in a short trials program at Darwin, called Advocate. Essentially Advocate was a sales pitch: a demonstration of Rapier's potential under tropical conditions to the Australian military staffs who were considering buying it. The assembly at Darwin was numerous because there were not only the military spectators and JSTU men, but the target operators and safety staff from Woomera and the WRE and BDRSS representatives. The demonstration was impressive, for two Rushton targets and a Meteor were destroyed in seven successful launches, with only one failure. Nevertheless, four years passed before the Australians signed a contract worth £20 million with BAC for the supply of Rapiers.

For all its success Rapier suffered from the usual handicap of optical systems: it needed good weather to function. BAC had long cherished the hope of reviving their radar tracked PT428 project, and indeed had had the foresight to design Rapier so that the conversion from optical guidance to radar would be practicable. After the American Mauler was cancelled, the Corporation was rewarded with an invitation to do an assessment study for such a modified version. During the later full development contract of June 1968, Marconi Space and Defence Systems joined the consortium to produce the new ancillary radar, which was called DN181 or Blindfire. Woomera was again used only in the evaluation phase, although there were some preliminary trials as well to test a refined optical sighter. This time the launching site was Area 5, left silent and bare with the abandonment of the Black Arrow satellite launcher in 1971. Now it was very briefly revived for Blindfire in the dying years of the project.

By February 1973 another Trials Unit, 23 JSTU, was assembled at Woomera under Lt Col Goodeve-Ballard. Although it was midsummer the weather was appalling. Storms lashed the ranges and the following summer the houses of the village were invaded by hordes of mice fleeing south from floods in the Centre.[71] These domestic difficulties did not prevent the first phase, using optical tracking, beginning on time. By June nine missiles had been fired at Rushton targets or else on programmed trajectories. There was only one failure, but then the run was broken by two consecutive live firings which lost their flight control. Twelve extra missiles were fired in August to investigate this, but the fault did not recur and eventually the repetition was put down to coincidence. The overall success rate of these optical trials was 73 per cent.

The radar tracking equipment arrived in September and was quickly installed. Within two months the Blindfire system was fully operational. After a short pre-evaluation phase running up to the end of the year, the main evaluation program began in February 1974 when work resumed after stand-down. Apart from a few delays caused by the unseasonable rain and a brief shortage of targets, it went according to plan and was finished on schedule in October. Thirty-four missiles were fired. The twenty-six successes included nine direct hits, eleven near misses and six deliberate turn-aways. Only two failures were due to missile defects; the rest were attributed to the weather or to ground equipment faults. By early 1975 most of 23 JSTU had returned to Britain, leaving behind a small group to help deal with the vast quantity of data-processing. Mathematical modelling exercises continued through the year and into 1977.

Rapier went into service with the British Army and the RAF regiment and was judged highly successful. Its deadly efficiency was demonstrated in the Falklands War against Argentine aircraft. The optical and Blindfire versions of Rapier proved most profitable for BAC on the export market too. Bought by the armed services of eleven nations including Australia, earnings reached £400 million by 1976 and the Corporation won two Queen's Awards to Industry as a result.[72]

Rapier in use during the Falklands War. (IWM)

We have seen that when a trials program for Sea Dart Mk 2 was proposed in 1979 the run-down of the Range had already gone too far to permit it. In fact the end of the Mk 1 trials in 1976 marked the end of all guided weapons work at Woomera. Some large unguided rockets continued to be fired in connection with British weapons systems up to 1979, but then these ceased too. Britain, of course, has continued to develop guided weapons. The Weapons Departments at RAE have evolved ever newer air-to-air and sea-skimming missiles, but the government has had to find other ranges on which to test them. The air-to-air Skyflash, for instance, an advanced version of the American Sparrow, was taken to the Californian Point Mugu range for its acceptance trials.

Australian work continued at Woomera up to and beyond the end of the decade but, with the progressive withdrawal of staff and the demolition of many Range facilities, it was limited to occasional trials campaigns of aircraft, sporadic minor rocket firings and bomb drops. The latter included the development of the Karinga cluster bomb, later cancelled. In 1980 navigational trials were proceeding in support of the Barra submarine detection system, an Anglo-Australian enterprise which continued despite the closure of the joint project.

Notes and Sources

1. In a much later development, the operator's task was taken over by a computer, using television or radar to track the missile and target and radio commands to correct the missile's course as it flew.
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3. A. R. Adams, *Good Company: the story of the Guided Weapons Division of British Aircraft Corporation*, BAC Guided Weapons Division, London, 1976, p.4.
4. Report S56/35 on a September 1956 visit to USA. Historical Folder No. 1.
5. Contribution titled 'No 6 Joint Services Trials Unit' from Group Captain A. C. Rawlinson dated 5 December 1983.
6. From an appendix 'Australian Fireflash acceptance trials 1955-57' to a contribution dated 1 January 1984 from J. W. Dodds.
7. Lt Col A. G. Cairns and Operational Safety Committee, 'Fatal accident with Blue Jay missile at Woomera Technical Area, 19 April 1956'. Report WRE 1 (October 1956).
8. Addendum to minutes of R&D Board of Management meeting 11/60. File MP5412/ 1/1 **£**
9. Planning Specification WRE 205 issue 1 (October 1959).
10. British Defence Research and Supply Staff status report (July/December 1960).
11. Red Dean design compendium (c. 1956-57) part 1, section 2.
12. Report 'Requirement of Red Dean trials in Australia' dated 17 February 1954 by Vickers-Armstrong Ltd.
13. 'Minutes of discussions with Sir Steuart Mitchell and UK party at WRE April 11-12, 1956'. Historical Folder No. 1.
14. WRE progress report January-June 1956.
15. Adams, p. 106.
16. Red Dean design compendium (c. 1956-57) part 1, section 1.
17. Adams, p.20.
18. Contribution dated 27 November 1979 from R. A. Cocke, British Aerospace, Bristol Division.
19. Anon, 'History of the Royal Australian Artillery in Australia', (c. 1974).
20. Cocke.
21. Addendum re Bloodhound 1trials to minutes of R&D Board of Management meeting 7/62. File F5149/1/1.
22. Adams, p.54.
23. One sphere was suspended below the other to pose a discrimination problem for the missile: the homing system should not be distracted by a weak side echo from the wrong target. Spheres were used because the effective echoing area can be calculated precisely.
24. Adams, p.48.
25. Supporting paper P(59)9 to CUKAC meeting No 45 (July 1959).
26. WRE Planning Specification No 1002, issue 3 (March 1965).
27. Directorate of Guided Weapons Research and Development Newsletter No. 3 (March 1948).
28. DGWRD Newsletter No. 3 quoting RAE Technical Note GW 11.
29. Report of the Directorate of Guided Weapons Research and Development to GW Progress Committee (January 1950).
30. Trials report LRWE TR24 (February 1954).
31. LRWE Trials progress report (December 1954).

32. Memo dated 8 July 1957 from Controller WRE to CGWSO BDRSS(A). File F5423/1/1.
33. Telex dated 12 August 1960 from DGW(N) UK to BDRSS Melbourne. File F5423/1/1.
34. Preliminary information paper on Seaslug Mk 2 R&D trials (October 1960).
35. Planning Specification WRE 1010, issue 2 (October 1964).
36. WRE Trials Wing Planning Specification No 2 (April 1971).
37. Seaslug Mk 2 separation improvement trials: completion report to Technical Committee meeting 4/75.
38. British Defence Research and Supply Staff status report (June 1972).
39. Adams, pp.56-7.
40. British Defence Research and Supply Staff status reports (May 1961-November 1962).
41. UK Ministry of Defence press release dated 4 August 1962. File F5421/1/1.
42. Adams, p.96.
43. Contribution from W. T. S. Pearson dated 18 March 1981.
44. The smaller chamber of the Stentor engine was also used in building the 4-chamber Gamma engine for Black Knight.
45. Instrumentation specification WRE 185, issue 2 (July 1960).
46. Pearson.
47. British Defence Research and Supply Staff status reports (November 1963 and January 1965).
48. Closing down specification WRE 1015, part 8 (January 1965).
49. Contribution from Brigadier J. P. Gwynne Lewis dated February 1980.
50. Toolondoo apparently means 'swamp'—hardly appropriate for an anti-tank weapon.
51. Planning Specification WRE 190 (October 1962).
52. This was not quite the end of the story of portable guided weapons at Woomera. In 1974 another British infantry weapon, Blowpipe, was brought to Woomera for about sixty evaluation trials. Blowpipe was a short range missile launched from the shoulder and intended primarily for defence against low aircraft. It was a daylight only weapon, as both missile and target were visually tracked in flight. Blowpipe was accepted by the British Army and was still in use in 1985, supplemented by a number of improved variants. It sold to at least ten countries and also figured in the Falklands War. The Australian Army, however, preferred a similar American weapon called Redeye, which was also tested very briefly at Woomera and is still in service.
53. Reported by J. C. Wisdom in his unpublished history of defence science and technology in Australia.
54. Planning Specification WRE 1005, issue 2 (August 1962).
55. British Defence Research and Supply Staff status reports (November 1963 and June 1964).
56. Planning Specification WRE 1049 (October 1966).
57. Planning Specification WRE 1056 (February 1968).
58. British Defence Research and Supply Staff status reports (December 1969 and December 1970).
59. Submission to 1PB Technical Committee (December 1974).
60. Report of mission visit, 19-22 February 1979. WRE document TRL 0016-SD.
61. Planning Specification WRE 1067 (November 1970).
62. Proposal for a supersonic rocket target service. Issue 1 (September 1969). The Petrel target was also used for a few Sea Dart trials in 1973-74.
63. British Defence Research and Supply Staff status report (June & December 1973).
64. 'The year of the Navy'. Undated contribution by an anonymous member of 25 JSTU.
65. WRE Trials Wing Planning Specification No 8 (May 1975).
66. Adams, pp.l 30-9.
67. S. C. Dunn, 'Rapier', *journal of the Royal Aeronautical Society*, (October 1970) 847-8.
68. Major F.L. Fuller, 'With 21 JSTU at Woomera', *Journal of the Royal Artillery*, (September 1970) 146-8.
69. L. A. Nicholls, 'The 21 JSTU Rapier evaluation trials'. Contribution dated 28 October 1983.
70. Fuller, 148.
71. Undated contribution on 23 JSTU from Col M. Goodeve-Ballard.
72. Adams, p. 185.

18 Jindivik and other hunted ones

FROM HUNTER TO PREY

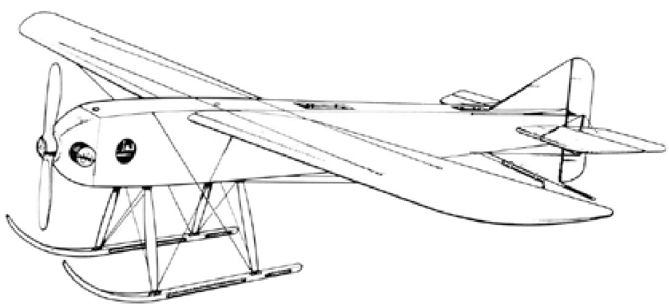
Although today it is natural to think of guided weapons as being propelled by rockets, the early history of guided weapons in fact predates rocketry and belongs instead to the first days of aeronautics. For no sooner had practical designs for aircraft begun to appear on the horizon at the turn of the century than military engineers began to dream of an aerial torpedo: a pilotless flying machine that could be set to drop its bombs on enemy territory. The first work seems to have been done in America by the Delco and Sperry companies in 1917. They invented a pilotless wooden biplane known as the Bug, which was powered by a small Ford engine. Its 135 kilogram bomb accounted for half the weight. Just as Jindivik was to do much later, the Bug took off from a carriage, although in this case the carriage ran along a track. The Bug was not controlled from the ground. It had a primitive autopilot consisting of a small gyroscope to hold a course and an aneroid barometer to control altitude. The duration of its flight was determined by a device which counted the engine revolutions. When the pre-set total had been reached a cam withdrew the bolts holding on the wings, which dropped off. The bomb then fell on its target.

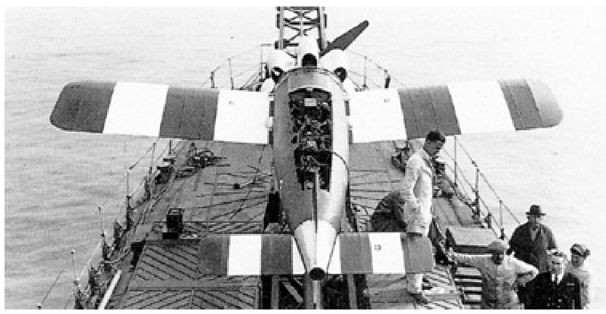
At about the same time the first British experiments were being carried out into a radio-controlled flying bomb. As the time was late in World War I, the project was disguised by the name of 'AT' or 'Aerial Target'. The aeroplane was a monoplane built by the Royal Aircraft Factory at Farnborough with some simple radio control of the rudder, elevator and throttle, and it was launched from a trolley running down an inclined track. Several prototypes of AT were ready for flight testing by the summer of 1917, but as each of the first three trials resulted in a crash, the project was abandoned.

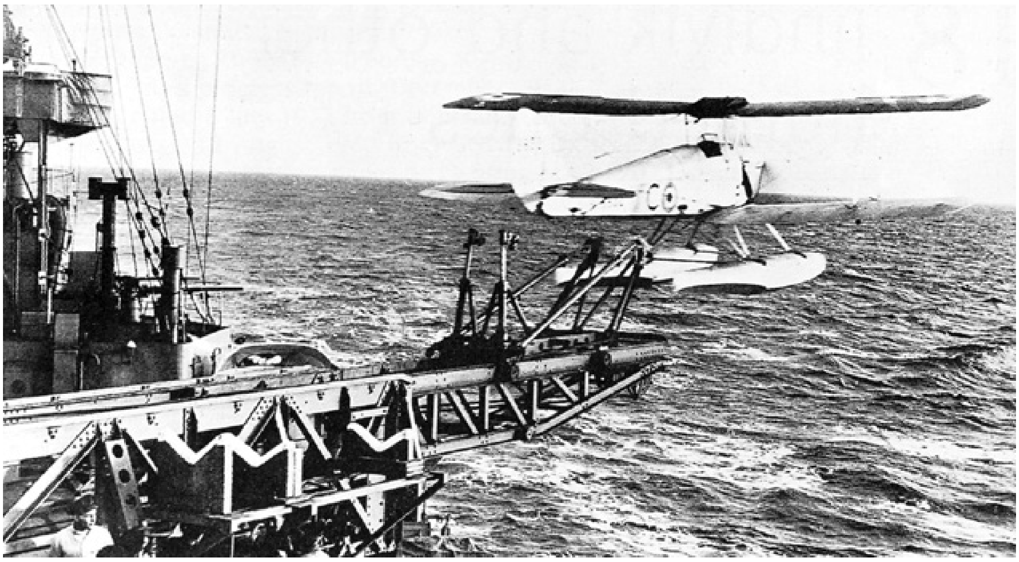
After World War I British experiments into pilotless aeroplanes continued at the Royal Aircraft Establishment (RAE) and resulted in the first effective bombardment missile. Called Larynx, it could carry a 113 kilogram bomb 160 kilometres at 320 kilometres per hour. It was not radio controlled. Its flight altitude was controlled by gyroscopes spun by compressed air and its range was set by a counter driven by a propeller. However, Larynx was particularly notable for the radio transmitter it carried on board. This emitted a continuous signal, but the pitch of the signal varied with the engine speed and was interrupted periodically by the revolution counter. The whole arrangement was very probably the world's first airborne telemetry system. Despite good trials from a ship and in the Iraqi desert, Larynx had no successors save for some design studies. The idea of a pilotless offensive aeroplane languished everywhere until 1942, when the Germans started to design their 'Doodlebug' or V1. The V1 flying bomb used much the same guidance system as Larynx had done fourteen years earlier.

Below left: 'Aerial Target', a pioneering British pilotless aircraft (RAE).

Below: RAE Larynx No. 3 on its ship-borne launching rails in October 1927. The top panels have been removed, exposing the control, autopilot and radio equipment. (RAE)







A Queen Bee target aircraft is catapulted off a Royal Navy warship, probably in 1939. (RAE)

During the later inter-war years British interest in pilotless aircraft turned instead to the design of a target plane which had enough performance and manoeuvrability to simulate a bomb and torpedo attack on a warship. The RAE's engineers came up with the successful Queen Bee in the mid-1930s. This was a derivation of the De Havilland Tiger Moth biplane, at first launched by shipboard catapults and landed on the sea, but later modified to take off from and land on runways. By this time the on-board controls and the autopilot had been perfected to the point where the plane could land completely automatically if the radio link were lost. The use of Queen Bee continued until late into World War II and altogether 420 were built. Some survived many attempts by trainee anti-aircraft batteries to shoot them down. The lessons learnt with Queen Bee and the Airspeed Queen Wasp were later applied to good effect during the development of Jindivik.

THE BIRTH OF JINDIVIK

The real stimulus to produce a high performance jet-propelled target came immediately after the war as soon as Britain determined to embark on the development of air-to-air and surface-to-air missiles. Such missiles inevitably have the most demanding and expensive trials requirements, because to test their mettle they must some times be launched against aircraft whose characteristics approximate the real thing. A weapon designed for use against a high performance fighter plane cannot always be fired at a lumbering old surplus aircraft.

The planning of Jindivik[1] (or 'Project B', its early title) was therefore contemporaneous with the foundation of the joint project. The need for a new target aircraft, and for runways at the rangehead from which it could operate, was being discussed as early as July 1947, alongside the arrangements for establishing the Long Range Weapons Board of Administration and Woomera itself. That November Prime Minister Chifley informed the Ministry of Supply in London that the nucleus of a team capable of designing a small unmanned jet plane had already been assembled within the Australian Department of Munitions.[2] The head of the team was Ian Fleming, a brilliant design engineer who more than anyone deserves the title of 'father of Jindivik'. Fleming had already worked at RAE in the year 1946-47, and he returned to Farnborough in January 1948 to discover what the Ministry of Supply had in mind and to bring back the specification to Australia to see how feasible it would be to build it there. Fleming quickly discovered that nothing detailed existed on paper:

> The first sight we had of a requirement was a small handwritten piece of paper on which were scrawled some performance figures (500 miles per hour at 40 000 feet and 75 minutes endurance at altitude are two I can recall) and the statement that the power plant was to be a straight jet development from the Armstrong-Siddeley turbo-prop 'Mamba' engine to give a little more than 1000 pound static thrust at sea level. That engine came to be known as the 'Adder'.[3]

Once Fleming and his British colleagues set to work the basic elements of the design soon jelled. Within three weeks the critical dimensions of Jindivik were set for good, and with such precision that when the prototype took to the air in 1952 its all-up weight was only 22 kilograms more than had been planned five years earlier. Indeed, the main design features lasted unchanged through all the successive versions over 30 years or more. From first to last Jindivik took off from a trolley and landed on a retractable skid. To prevent its swinging sideways on landing, one proposal was to use a sharp front skid penetrating the runway for a centimetre or so, but not digging in so far that the aircraft tipped over on its nose. The most suitable surface was thought to be a thin layer of sand over asphalt, adjusted to the right density.[4] The final design for the single skid gave it a pair of replaceable blades on either side of its heel.

After a busy ten weeks Fleming returned to Australia in March 1948, to the Government Aircraft Factories (GAF) at Fisherman's Bend, Victoria, which had been entrusted with the final design and construction. By this time it had been decided that Britain would develop the engine, and RAE and LRWE between them would take on the control equipment and instrumentation. The small design team at GAF under Fleming—it never amounted to more than twenty-five engineers and draftsmen throughout these early years—received permission to proceed in June 1948. Another dominant figure in these early years was Bob Leslie, a steady calm man who first went to the Radio Department at RAE as a trainee and then took the lead in many aspects of the project when he returned home in September 1950. He later became a popular head of Target Aircraft Group (TAG) at Salisbury, and it is an interesting reflection of the success of the trainee scheme that three other permanent heads of TAG—Grahame Lister, Brian Deegan and R. J. (Rocky) Rockliff—had also served a spell at Farnborough in 1948-50. As the trainees returned the work began to build up and soon groups of people at Salisbury and Farnborough were hard at work developing the telemetry transmitters, the trolley steering gear, the autopilots, a 50 centimetre transponder to help the tracking radars, and what was called a 'proximity device' to measure near misses.[5] Some studies were also made of the effect of weather on the accuracy of observations.

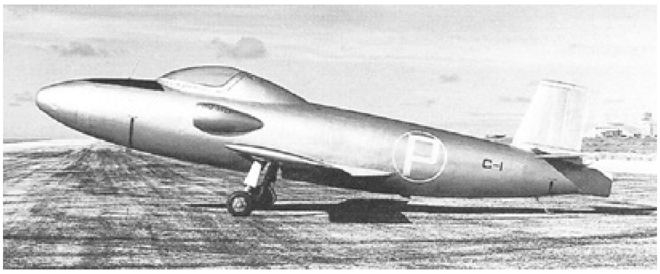
R. A. (Bob) Leslie.

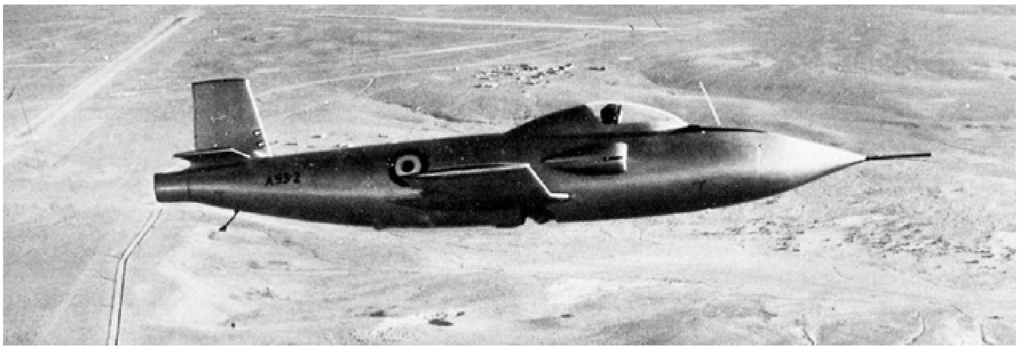
The Australians' first task was to build eight prototypes: two piloted and six pilotless versions, the former for flight test purposes only. Though he was overruled, Fleming argued strongly against the manned version. He thought it was too taxing an assignment to build two variants with a sufficient degree of commonality. He feared that to design a piloted version with enough space and an acceptable undercarriage system would mean compromising the design of the pilotless version. In the event the two variants were structurally almost identical, but the layouts of the central fuselages of the two were very different. The manned version (Pika, from an Aboriginal word said to mean 'flier') carried much less fuel and had an endurance of only about 30 minutes. It had a conventional, if very small, retractable undercarriage. It could be flown either with manual controls, by a set of push buttons through the automatic controls, or from the ground with the pilot acting as monitor only—and resisting a strong temptation, no doubt, to take command.

On the last day of October 1950 the onlookers at Woomera airfield saw the little Pika lift off under the control of John Miles, GAF's test pilot. After a few preliminary difficulties—Miles could not get the machine to unstick from the run way—the Pika soared surprisingly high into the air before being put down safely. The further test flights were uneventful except that on the third the undercarriage jammed up and Miles had to bring it in to a belly landing, without doing much damage. This first Pika to fly was wrecked in a serious accident in April 1951 while under the control of Flight Lieutenant Fred Knudsen. The engine stalled during a slow fly-past of a VIP party and the aircraft dived to the ground. Knudsen suffered multiple fractures of the spine and was in hospital for many months, though eventually he recovered fully.

Below left: Pika No. 1 on the runway at Woomera . . .

Below: . . . and after its belly landing in early 1951.





Pika No. 2 in flight over Woomera airstrip.

Between them the two Pikas notched up a hundred flying hours with only one other serious incident. Jindivik was to be landed under visual control from the ground, and so it was important that its colour should give the maximum possible contrast against the sky. Pika was painted various colours to investigate this, and one of the paints tried had a granular texture which produced a surface finish almost like sandpaper to the touch. On the first take-off in the new colour the Pika only just staggered into the air before the shaken test pilot ran out of runway. No one had realised just how drastically the rough paint would disrupt the flow of air over the plane's skin.

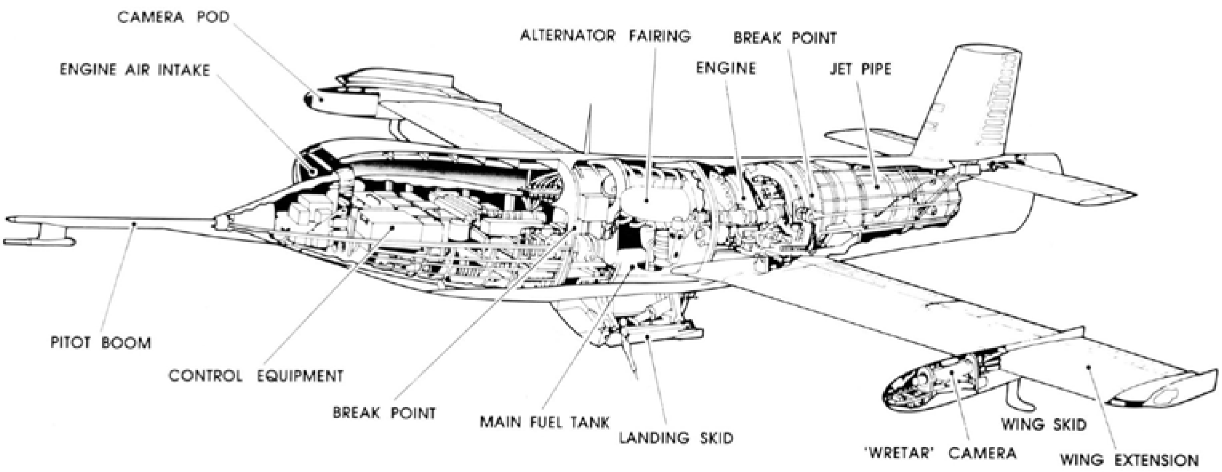
The Pika trials, which ended in June 1954, were otherwise uneventful and the surviving Pika is still to be seen in the RAAF museum at Point Cook. Certainly the flights were invaluable in training the crews and proving the design. One of the main conclusions was that a rudder and its operating mechanism could safely be dispensed with—an important cost saver. As the results of the Pika trials came in, work on Jindivik had continued and the prototype was ready for its first flight at Evetts Field in August 1952.

FLYING JINDIVIK

Since the design and operation of Jindivik remained fundamentally the same through out, it is convenient to give a general description here so that the succeeding account of the first trials and the later modifications will be more comprehensible.

Technically Jindivik was a metal low-wing cantilever monoplane of conventional design. It was 7 metres long and had a wingspan of 5.8 metres. The wings were rectangular in plan, a design chosen for economy, but it had the fortunate consequence later that extensions could be added outboard of the camera pods on the wing tips to give more lift at high altitudes. It had a fuselage of semi-monocoque construction, built in three sections for ease of transport and servicing. Most of the controls and instruments were in the front section, the upper half of which was detachable. In the centre section was part of the engine, some of the pneumatic gear and a storage bay for the special target equipment. Here also was the main fuel tank, giving an endurance of about ninety minutes, depending on how hard it was being worked. Below this central section was the landing skid. The rear section was filled with the engine and the jet pipe.

Jindivik was built in three sections for ease of servicing and transport. This diagram shows wingtip extensions fitted outboard of the wingtip camera pods, to give more lift at altitude.



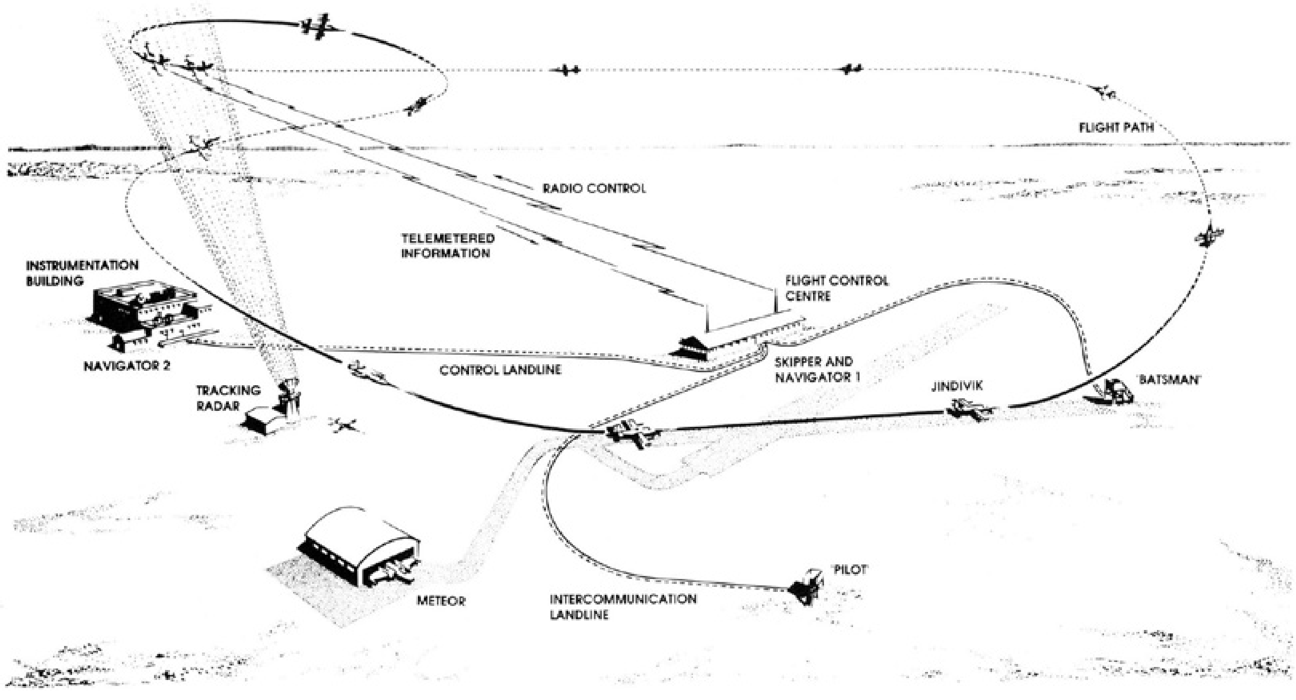
The electrical power required by the aircraft was generated from the engine with a battery back-up able to maintain the essential functions for twenty minutes. The flaps and the retractable skid were directly operated by compressed air stored in a tank.

Four people normally flew Jindivik into position for the trial and landed it afterwards. Two of them, the skipper and the navigator, sat side by side at a console in the Flight Control Centre at Evetts Field, at the centre of an elaborate web of telemetry and radio control gear. The other two, the batsman and the pilot, stood on portable towers next to one of the two intersecting runways of Evetts Field. The batsman stood at one end of the runway either behind or head-on to the plane, with the pilot at the side of the runway opposite the required touchdown position. The batsman controlled the aircraft by means of left and right radio commands during both take-off and landing, but the pilot's task mainly was to control the ticklish approach and landing. In either case, during the missile attack (or whatever the purpose of the trial happened to be) Jindivik was under the command of the skipper. The navigator, in conjunction with a second navigator in the Instrumentation Building at the rangehead, monitored the instruments—telemetry and radar plotting table—and transmitted the skipper's instructions. Jindivik contained a fairly simple telemetry system which radioed back several channels of flight information. Initially these gave the air speed, engine speed, vertical speed and vertical acceleration of the aircraft.

At first a Jindivik in flight was accompanied by a shepherding aircraft (the two seat version of the Meteor), which was fitted with a duplicate set of Jindivik controls in the rear seat. The suggestion was even floated that the shepherd should be armed to shoot down the Jindivik if it ever looked like menacing people on the ground. Shepherding was abandoned when the crew gained confidence in interpreting the telemetry and tracking displays. Another plan was to install a command-destruct system using explosive bolts to blow off the tail, but this was given up when the ground tracking and display was improved with a predictor and vertical plotting table.[6]

The radio controls at first used bulky and fragile valve circuitry which grew vastly more sophisticated, compact and light with the arrival of solid state electronics; but in the beginning the design allowed for twenty-four switched commands, which were more than sufficient both to control the flight and to operate remotely the cameras and other trials equipment. In the uncluttered ether around Woomera, a transmitter of only 50 watts gave a range of at least 160 kilometres when the Jindivik was flying at a height of 10-40 000 feet. When a command was selected, a combi nation of two out of eight audio tones modulated the output of the transmitter. In the aircraft the signal operated electromechanical relays which in turn passed on impulses to the autopilot, the aircraft actuators or the special equipment. Most of the commands remained in effect until cancelled by a later one, but to

The pilotless Jindivik actually had a crew of four, all on the ground. The batsman and pilot controlled takeoff and landing by eye, while the skipper and navigator used two-way radio signals and radar plots to command the flight.



give a proportional control some commands—e.g. left, right, pitch up, pitch down, throttle open, throttle shut—could be 'beeped' by holding the control down until the desired response was achieved. So that the aircraft could respond to simultaneous commands from two crew members, for instance pitch up and left, a time sharing system was used, in which the transmitter received its input switched alternately and automatically from two sets of control buttons. An independent emergency system duplicated the essential flight controls.

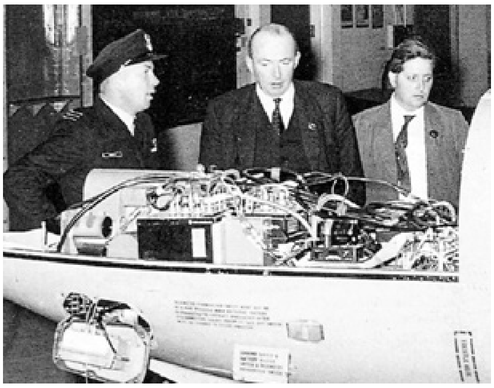
For take-off, Jindivik rested with its landing skid retracted on the three sup porting arms of a tubular steel tricycle trolley. The trolley was untracked. As it sped down the runway a gyroscope linked to a servomotor on the front wheel stabilised and steered it. (Later the gyro steering was dispensed with and the combination was steered by the batsman's commands to the Jindivik.) At about 110 knots the aircraft rotated upwards on the trolley and at the right angle of incidence lifted from the supporting arms, which folded down as the Jindivik climbed away. A flash bulb detonated to signal the exact moment of release, and the trolley automatically braked to a halt.

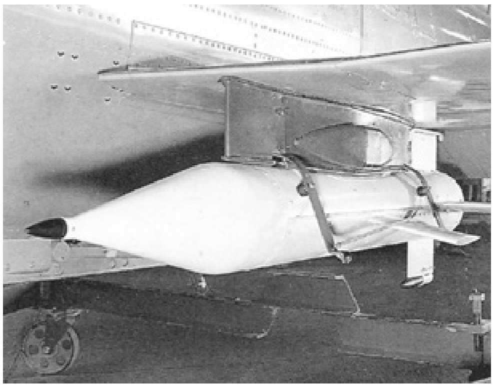
While in level and uneventful flight Jindivik flew under the control of its on board autopilot. As in a piloted aircraft, this consisted of a set of gyroscopes to measure changes in flight attitude, and the electronic circuitry to provide a correction to the proper control surface. It also had a barometric system to hold the aircraft at a selected altitude.

The most important standard trials instrumentation carried aboard the Jindivik were the cameras mounted in pods faired into each wing tip. Thanks to the very compact WRETAR camera with its fish-eye lens described in Chapter 14, these pods were only 14 centimetres in diameter. At the appropriate moment in the trial the recording cameras were switched on by radio to film the missile during its attack approach. Even if the missile destroyed or badly damaged the Jindivik, the film records were usually recoverable, and from them was computed just how closely the missile had approached the target, including angles and time as well as distance. The relative attitude of the missile could also be measured.

The cost of Jindiviks rose steadily with the years, and by the end of the project in 1980 had reached some $600 000 each. Obviously a trial which justified actually blowing one out of the sky was a rare event, and in fact deliberate strikes accounted for only fifty or so Jindiviks all told. (The record number of kills went to the Blue Jay air-to-air missile, which accounted for nineteen.) To economise on Jindiviks, much effort went into designing suitable bodies which could be towed below the plane to provide a cheap and disposable target which the missile could actually strike. WRE developed an effective system called Tonic in which two torpedo like bodies were stored under the wings close to the fuselage, from where they could be streamed out and winched in as required.[7] The missile's interception with the Tonics could be photographed from the Jindivik. To augment its image each Tonic could carry a radar transponder or reflector for radar-homing missiles or six flares to provide a lure for infra-red homing missiles. If two Tonics were deployed simultaneously it presented the missile with a nice discrimination problem.

The weapons trials required the Jindivik or other target to be presented at a wide range of speeds, altitudes and manoeuvres on approaching, receding or crossing tracks. Normally the four-man operating crew was sufficient, but for more complex presentations the target had to fly at altitudes as low as 50 feet or in pairs. For very low flying a radio altimeter was coupled into the autopilot with a 'height lock' arrangement. For close line abreast flying, some special techniques were developed. One plane became the 'master' and the other the 'slave' and for easy optical identification from the ground the master carried



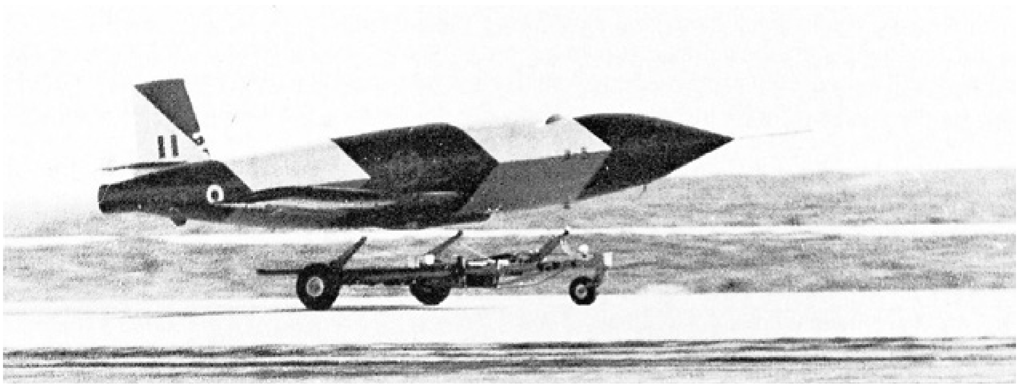


Right: RAAF CO Fred Inger explains the Jindivik autopilot to visiting UK Defence Secretary Peter Thorneycroft (*centre*).

Far right: A Tonic tow in position under a Jindivik wing.

a smoke generator and the slave an oscillating lamp. The slave was kept under inspection via a television link from the master to the ground control, and the separation distance was constantly monitored by a radar unit in the master with the data telemetered to the ground and used, together with the television picture, by the second navigator. The whole arrangement was complicated and, despite all the electronic aids, was extremely tricky for the operators to handle.

At the end of the trial the target—presuming it had survived—was set circling the airfield. When the batsman and pilot had it in sight through their special binoculars fitted with graticules for estimating image position, control was handed over to them. The batsman could issue turn commands only. The pilot normally used only pitch and throttle commands, but he was provided also with the essential flight attitude commands in case an overshoot and a second approach had to be made. In an uneventful landing the batsman brought the aircraft on to a suitable track and the pilot controlled the glide path and round-out for touchdown on the extended skid.



The moment of take-off from the trolley on the first successful Jindivik flight, 28 August 1952.

FIRST TRIALS

Our story now reverts to 8 August 1952, when all was at last ready for the first flight attempt by the RAAF's Aircraft Research and Development Unit Trials Flight (later No. 1 Air Trials Unit). At Evetts Field, which had been built for target aircraft trials near Koolymilka and the rangehead, the facilities were none too luxurious. A number of mobile vans held the radio, telemetry and radar equipment. The only fixed buildings were a small aircraft hangar and a primitive bush toilet. The latter featured a deep trench with a row of seats above partitioned off into 'men' and 'ladies'. To keep everything hygienic and to destroy the redback spiders, the cleaner was given to burning aircraft fuel in the trench. On one occasion he slopped in the fuel and tossed in a match from the 'ladies' side. The resulting *whoosh* was accompanied by a loud cry from the other side. The victim stumbled out in a state of shock, trousers round his knees, to be confronted by twenty pairs of eyes taking it all in from a bus that had just arrived at the hangar.

The first trial quickly proved to be an anti-climax, made more so by the months of preparation that preceded it. On the take-off run the trolley started straight but then curved off the airstrip and into the rough, damaging both plane and trolley. It emerged that in the excitement one of the ground crew had forgotten to uncage the trolley gyroscope. On the second trial about a week later the Jindivik reached take-off speed but refused to leave the trolley. The two careered on until they ran out of runway. The Jindivik came off in the jolting and made a brief unpowered flight before crashing, but without damaging itself greatly. The cause was a microswitch failure.

It proved third time lucky on the afternoon of 28 August 1952. Under the control of skipper Flight Lieutenant Tom Berry and navigator Flight Sergeant 'Blue' Gallagher a Jindivik lifted off its trolley and climbed smoothly into the air, whereupon the skipper delivered an immortal line, bowdlerised in the contemporary transcript of the recording as, 'FLASW1! It's taken off from the trolley! What the FLASW2 do I do now?', where FLASW1 and 2 stand for the two most common four letter Anglo-Saxon words.[8] Despite this initial consternation the flight lasted half an hour, controlled by the ground crew and a pilot in a Meteor shepherd, who had instructions to try to flip the Jindivik over with his wing if it suddenly ran amok.

Left: The Mk 1 Jindivik after the crashlanding that ended this first flight.

Far left: Prime Minister Menzies presses the button for Jindivik to take off on a demonstration flight in May 1953.

Everything went smoothly until the time came to land. On the approach run the signal 'land glide' was given, which lowered the flaps and landing skid and reduced throttle. But the aircraft stuck its nose up and stalled; then the nose fell and it became unstalled. This happened several times and no remedy suggested itself, so eventually the Jindivik was flown away from the airfield for the protection of people on the ground. In the following crash landing the machine was wrecked, although some parts were salvaged. The post-mortem found that the elevator trim in the autopilot was set at the wrong value. It was merely a matter of a black box adjustment and trials soon proceeded.

The Jindivik mortality continued to be high in these early trials. On the fifth flight the engine failed at 15 000 feet, but the shepherd guided it to a successful forced landing on Lake Hart. It took seven attempts before a Jindivik landed success fully, and three of the first five planes which took off were wrecked. Twice the Jindivik refused to respond to the 'pitch up' command in the last moments of landing, and the resulting impact with the ground was far too much for the skid shock absorber to handle. The cause was a totally unexpected human error. As Fleming tells it:

> It was some time before we found the unexpected reason. On each occasion two signals were sent simultaneously and were cancelling one another. There had been a cold snap at Woomera and the ground-based pilot handling the aircraft in the pitching plane was wearing heavy flying gloves. Because these effectively increased the size of his index finger, he was inadvertently operating not only the 'Pitch Up' button but also the adjacent button—it was quite by chance that he was later seen doing this.[9]

Some of these early trials were hair-raising. On occasion a Jindivik seemed to develop a mind of its own, stubbornly ignoring its master's commands, making suicidal low level passes over the desert or sudden aggressive darts at the shepherd aircraft. Once an autopilot was installed with the connections to the gyros which sense pitch and roll accidentally swapped over. At take-off the upward pitch of the plane was interpreted as a roll, and the autopilot tried to apply a correction. Matters got further out of hand as the crew intervened. The resulting flight was notable for some acrobatics unknown to aeronautical science and culminated in a ball of fire. On another occasion a Jindivik stuck firmly to the launching trolley and climbed away quite well with it still attached. The combination was gingerly put down on Lake Hart, but the soft surface caused the wheels to bog and the plane cartwheeled over. Then again, during one flight in June 1953 the shepherd aircraft lost sight of the Jindivik and soon after the radar transponder failed so that the tracking radar lost it as well. As the official record said drily, 'for thirty minutes the position of the Jindivik was not known'. Rather miraculously, the skipper seated at his control console was gazing up through the transparent dome above him when a tiny speck drifted into his limited field of view. This brief sighting was enough to allow the shepherd to be vectored on to it, and it landed safely after more than an hour in the air.

Altogether, in 1952 three planes were destroyed in the course of five flights, and in 1953 three more were lost in another twenty-six flights. Several others were damaged. In 1954 the loss rate was still running at one in every four flights. There was a particularly bad run in 1955, in which eleven Jindiviks were destroyed in thirty- seven sorties ('sorties' includes four aborted take-offs). The reasons for the crashes tell their own story: fuel exhausted, probably due to a leak; the plane broke up in the air when a plug became detached in the aileron control box; the engine failed at height when a lead came off a solenoid; an insulation fault in the wiring loom; a flap torn off in a fast glide; the flaps and skid failed to extend and the

Far left: LRWE chief Pritchard (*left*) anxiously crosses his fingers as the pilotless aircraft goes through its paces.

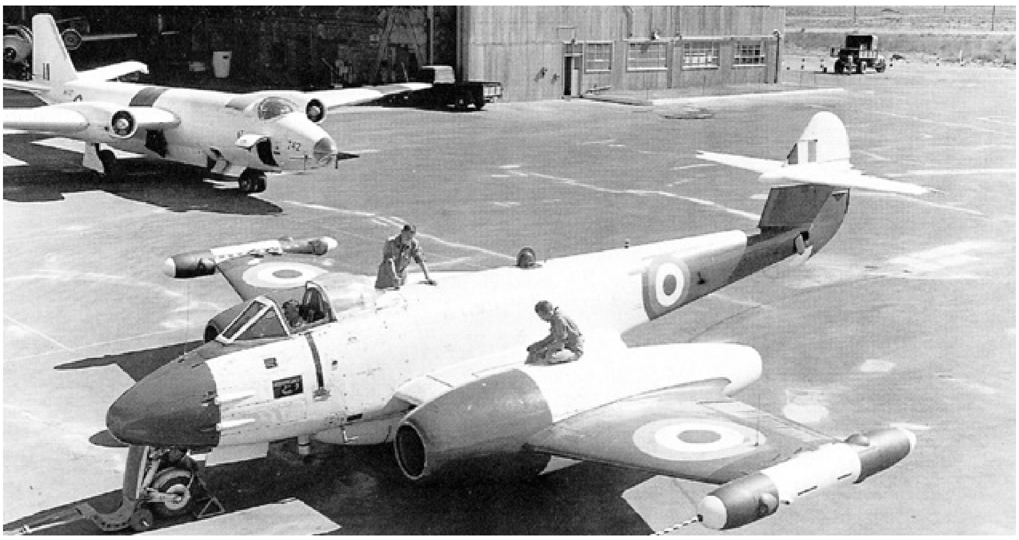
Left: A perfect landing! Minister of Supply Beale congratulates designer Ian Fleming (*centre*), while a relieved Pritchard looks on.

plane totally wrecked during an attempted landing without either. The team was learning the hard way that quality control and maintenance could not be sidestepped just because no human lives were at stake. If anything reliability had to be better than usual because no one was aboard to cope with small problems. Most of the headaches—and the crashes—were caused by nothing dramatic like structural failure but by, in Fleming's recollection, 'apparently mundane things like the standard of electrical connections—for instance, the inspection for dry soldered joints in multi-pin plugs and that type of thing'.[10]

METEOR AND CANBERRA DRONES

The purpose-built Jindivik was not the only pilotless target aircraft used at Woomera. Some Meteor fighters and Canberra bombers, retrofitted with remote controls and flown in much the same way as Jindivik, also filled that role. The Jindivik was a versatile design, but it could not be an ideal target for every guided weapon being developed under the joint project. In its basic or unaugmented form it had some deficiencies. The air-to-air missiles then being developed, such as Blue Sky and Blue Jay, had a range of around 5.5 kilometres, from which distance the small Jindivik was invisible to a fighter pilot. To overcome this limitation Jindiviks used in all of the air- to-air trials at Woomera were fitted with a 600-watt oscillating landing lamp in the rear fuselage. Actual size was not the only problem. Jindivik's single engine provided only a small image to the missiles which used infra-red homing systems, although the target's heat image could be enlarged by adding on-board electrical heaters and flares.

The Meteor was an obsolete twin-engined fighter plane, and when converted to a drone it was not a particularly satisfactory sort of target for the guided weapons being developed at the end of the 1950s. Its speed and climb performance was inferior to Jindivik's, and its ceiling was far lower. It was also more fragile. A Jindivik could land on its single skid even in quite rough terrain and was far less susceptible to cross-winds than a plane with



A pilotless Meteor (*foreground*) and Canberra at Evetts Field in 1962.

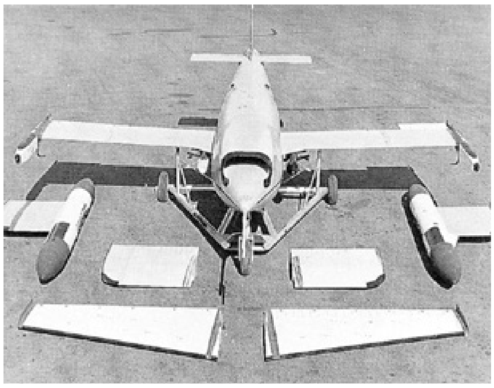
a conventional wheeled undercarriage. The Meteor's control equipment was complicated, unwieldy, and at first not very accessible: in the early conversions of the F-Mk 4 it was packed into whatever space was available and this was chiefly the ammunition and gun bays. (The later conversions, of the Meteor F-Mk 8, were more radical: the fuselage was lengthened in front of the cockpit, and this improved access greatly.) The main reason for using Meteors at all was the supposed expense of destroying Jindiviks in strike trials. In the early years the British rather exaggerated the rate at which Jindiviks would be consumed at Woomera. They had ambitious plans for missile development and they knew that the weapons would be fired under excellent conditions with a 'lethality rate', it was supposed, of close to 100 per cent. George Gardner, who had worked on Queen Bee and by this time was the Director of Guided Weapons R&D at the Ministry of Supply, estimated that even if it escaped being hit each plane might last for only ten flights. Thus they were expecting to write off targets in large quantities. Jindiviks were planned to be disposable in the last resort, but they were expensive pieces of equipment: in 1953, when the production run was beginning, they cost £5-7000 each, or about the same as one of the coveted brick houses then being built at Woomera. Cost, then, was a real consideration, and the old Meteors could be had for the price of the conversion equipment. The first unmanned Meteor, converted by Flight Refuelling of Dorset, flew at Evetts Field on 7 May 1957. It did not land as it was destroyed by a Fireflash missile. This was the first of 477 sorties which lasted until June 1974. Fifty-nine Meteors were destroyed in flight and twenty-two crashed through malfunctions. In addition, two piloted Meteors were used in the early 1970s to present towed targets for Seawolf, Rapier and Blowpipe missiles.

There were solid technical reasons for using the modern and expensive Canberra bombers as targets for ground-launched missiles like Bloodhound, Thunderbird and Seaslug. The main military urgency of the 1950s was to develop a guided missile which could offer a credible threat to a nuclear-armed bomber. The problem was that Jindivik presented only a small image on radar screens, equivalent to three square metres. Various reflectors could increase the apparent size, but not always as much as required. The Canberra produced a radar image ten times as large, more like the size of a putative enemy bomber, and its speed and ceiling were not much inferior to Jindivik's. Unfortunately it cost three times as much when destroyed, but sometimes, for instance when doing proximity fuze or warhead damage assessment trials, this could not be avoided. A total of seventeen Canberras for use at Woomera were converted to remote control by Short Brothers and Harland in Northern Ireland and flown to Australia. The first target flight was in June 1959, and on that occasion the bomber was destroyed from the ground while at 50 000 feet. Another eleven were shot down before the service ended in November 1965, and five more malfunctioned and crashed.

LATER HISTORY . . . AND A PROPOSED SUPERSONIC TARGET

The technical evolution of Jindivik was extremely rapid; indeed, work on the Mk 2 design began early in 1951, well before the first flight. This was the first production Jindivik and while it had the same external appearance as the Mk 1 it was a leaner, lighter and more powerful machine. The weight was reduced by more than 45 kilograms, mostly by replacing the actuators with ones designed at RAE. The old actuators had come from German war surplus stocks and were very heavy. Under the thrust of Armstrong-Siddeley's more powerful Viper engine, the ceiling went up to 48 000 feet and the maximum speed up to Mach 0.85. Eventually 114 of this mark were built, with another seventy-six of the even higher performance Mk 2B.

The later marks used ever more powerful versions of the Viper engine. The ASV11 engine gave the Mk 3 a ceiling of 60 000 feet thanks to its larger air intake. Nine of these were built. The Mk 3A had a more refined electrical system, a better autopilot, extra fuel tanks and could take a 2 metre wing extension for very high altitude trials. A total of 147 of these were built, with the first flight being on 10 November 1961. It could reach 65 000 feet, Mach 0.86 and, in level flight, 500 knots. Some experiments were even carried out with auxiliary rocket propulsion, when a Mk 3A was experimentally fitted with a small HTP/kerosene engine. The results did not justify any further work, for the performance was no better than the 60-70 000 feet attainable by the ordinary jet with its wing extensions. By the time the joint project ended, the current mark was the 3B, which had specialised modifications



Far left: Wheeling out a Mk 2 Jindivik.

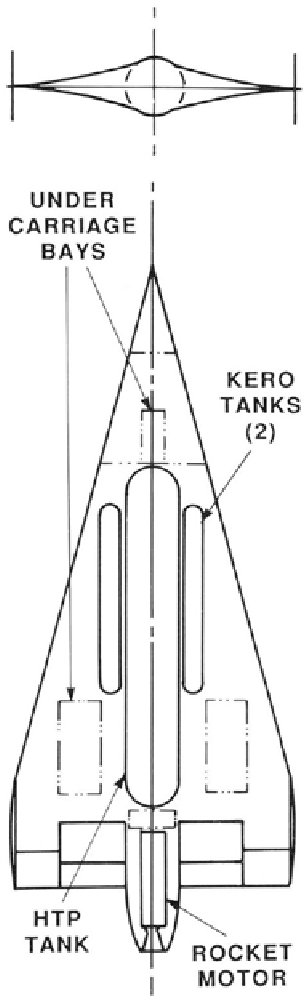
Left: A Mk 3A Jindivik with its available wing extensions.

to improve its fast low level performance. Its electronics—control and telemetry—had of course been much refined over the years. The 3B's performance was remarkable. Diving, it could reach 0.86 Mach and 500 knots in level flight. It could climb from 50 to 67 000 feet in an ascent steep enough to outperform the first-line fighter aircraft of the day. It had a range of at least 1440 kilometres and an endurance of 112 minutes. By 1977, 126 had been delivered or were in production.

While Jindiviks, Meteors and Canberras between them filled all the needs for a subsonic target over many years, the development of a supersonic target aircraft was looked at periodically and the same arguments came up each time. The rationale for a supersonic target was that in the absence of one having a performance comparable to that of 'state of the art' warplanes, there remains a dangerous ignorance about a weapon's real effectiveness. The opposing argument was that the development of a supersonic target from scratch would be extremely expensive and was not really worth the cost. Sufficiently trustworthy data could be obtained by extrapolation from trials using subsonic targets.

Of the several proposals for a supersonic target made between 1954 and 1959, the most promising was one known as Project K. The concept was of a delta-wing aircraft powered by a liquid propellant rocket engine derived from the Blue Steel and Black Knight engines. A Canberra would carry two such targets under its wings and launch them in the air. After a flight to 70 000 feet at Mach 2.5, the vehicle would be recovered by parachute. Nothing came of Project K, partly because the French ram-jet CT-41 supersonic target was then being developed by Nord Aviation in France and at its North African range. That target showed promise of being suitable for use both in Britain and Australia. However, CT-41 was eventually abandoned. Even as late as April 1964 Nord Aviation had completed only three successful trials with it.

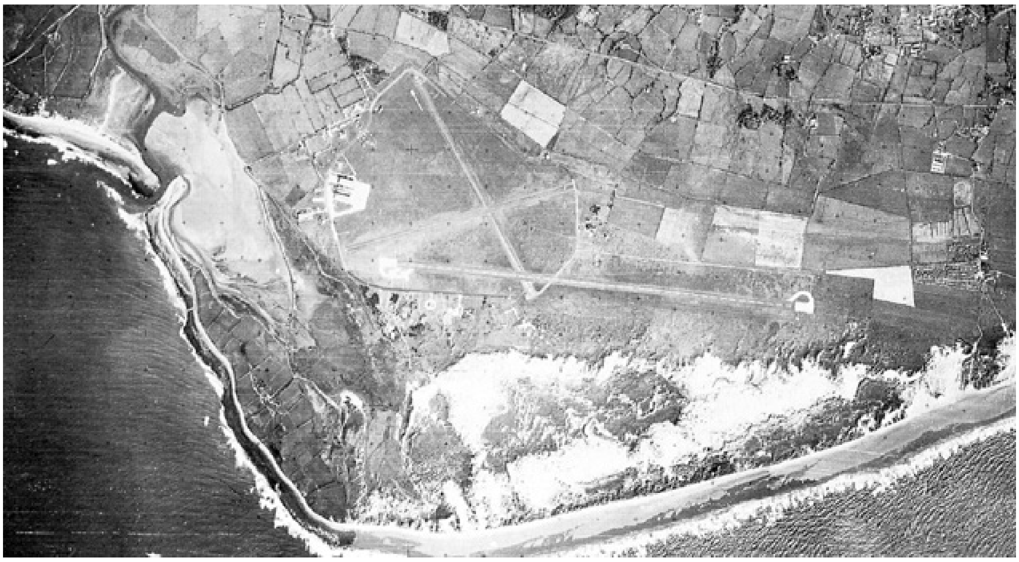
The idea was revived again in 1966, as part of the trials plan to exercise the Red Top missile. This time there was a feasibility study in Australia in which GAF, WRE, the British Ministry of Technology and Rolls-Royce all took part, and the project even acquired a name: Kareela ('south wind'). Kareela was based partly on Project K; it was to have been carried in the bomb bay of a Canberra, launched in the air and landed by remote control on a skid on an ordinary airstrip. The proposed engine was the liquid propellant Rolls-Royce BS640. But the approval to proceed never came; Kareela was cancelled and the idea of an Australian supersonic target was dropped for good. The only supersonic target ever deployed at Woomera was the British Petrel upper atmosphere rocket. Between March 1973 and August 1975, as described in the previous chapter, eighty-five Petrel presentations were made during Seawolf trials.



An early proposal, later abandoned, for a supersonic liquid rocket propelled target known as 'Project K'. It was to be launched from a Canberra bomber.

CUSTOMERS AT HOME AND ABROAD

The largest user of Jindivik has been the British Ministry of Defence. Since 1960 two hundred or more Jindiviks have taken off from the Llanbedr base near Harlech Castle in Wales and flown out over Cardigan Bay off the Aberporth coastal range, in trials totalling several thousand. The second largest, and of course the original, customer was the joint project, followed by the Australian armed services. Even a decade after the target aircraft service ended at Woomera in 1975, Jindiviks were still being ordered by the Australian Navy.



An aerial photograph of Llanbedr base in Wales (north is at the left). (RAE)

Jindivik was sold to two overseas customers. The first was Sweden, whose airforce took ten of the Mk 2 version for its Arctic Circle range as early as 1957. The other, more important, was the US Navy. The custom of the Americans was courted keenly, and in July 1962 a joint WRE-RAAF team of salesmen-demonstrators packed up a mass of equipment and three Jindiviks for transport to the US Navy's range at Point Mugu in California. When the Australians took the van over to the American freighter plane at Edinburgh for loading, they discovered that it stood too tall to fit in the freighter's hold. Working overnight WRE's tradesmen had to cut off the top so it could be stowed and reattached at the other end. Despite this stressful start the three Jindiviks did very well in California during their eleven sorties under Bob Leslie's technical leadership. On one of them a Jindivik excelled itself by reaching 65 000 feet or nearly 20 kilometres, a record altitude for a pilotless aircraft. At the end of another sortie one plane very nearly misbehaved itself, although the Australians managed to carry off the incident with some panache:

> At Evetts Field Jindivik invariably comes to a halt at a respectable distance from the batsman. However, on the first landing of the USA demonstration the batsman saw the Jindivik still sliding inexorably towards him well past the stopping place. But he stuck to his task and Jindivik eventually came to rest with its pitot boom accurately aligned on his midriff within what must have seemed like hand-shaking distance. The returning spectators were apparently much impressed by the batsman's performance and one of them was heard to exclaim excitedly, 'There you are, you see. I told you they could bring them right back!'[11]

In the following year there was another series of eighteen flights on San Nicolas Island offshore from Point Mugu. The US Navy was impressed enough to order forty-two planes but used them up quickly. The range at which the attack missile was fired was left to the ship's captain to decide, and he much preferred a sitting duck to boost the morale of his crew. The habit of firing from 9000 metres a missile with a capability of triple that distance adequately explains why the Jindiviks each made four sorties at most. The overseas sales were worth $34 million by 1977.

THE END AT WOOMERA

From the opening of Evetts Field in 1952 to the withdrawal of the service in 1975, the story of target aircraft at Woomera lasted for twenty-three years. For most of that time, until June 1967, all the sorties, airfield control and aircraft maintenance were handled by the Target Aircraft Squadron of a RAAF Air Trials Unit, with technical support from GAF and WRE. For the remaining few years after the RAAF relinquished technical control of Jindivik the daily work at Evetts Field was handled by a contractor who used experienced pilots, often ones retired from the RAF.

By the time Jindiviks ceased to fly at Woomera, 164 of the aircraft had taken off from Evetts Field on 1986 sorties, with another sixty flight attempts aborted at take-off for one

Jindivik WRE 418, survivor of 285 flights, being serviced by a Short Bros and Harland crew at Evetts Field. A Jervis Bay Jindivik has since eclipsed this record with 324 flights.

reason or another. Fifty-two Jindiviks had been destroyed by weapons and 105 had crashed through malfunction. This ratio of about 1:2 is not too bad when it is borne in mind that practically all of the developmental flying was done at Woomera. The overall statistics give a much more favourable picture.[12] In later years Jindivik's reliability increased so markedly that one plane made 285 flights over ten years before being shot down by a Rapier missile in 1974. According to the commanding officer of the trials unit, Col Mike Goodeve-Ballard, feelings ran high when his Rapier proved too good for this battered Jindivik, and he was not quickly forgiven by the target service people who had patched it up and put it back in the air so often. One factor in this excellent performance was the intrinsic durability and resilience of the design. Planes limped home with almost unbelievable amounts of damage after missile strikes.

Jindivik was and is the most versatile, reliable and economical subsonic target aircraft produced anywhere. It was still in production and use at the end of the joint project and still had some years of life ahead of it, although by this time the airframe had been pushed close to the limits of its performance. At the RAN'S Jervis Bay Missile Range south of Sydney a private contractor, Fairey Australasia, operates Jindiviks for the RAN. Guided from the control complex on Bherwerre Ridge, Mk 203 Jindiviks are still being flown out over the sea as targets for the latest sea-to-air and air-to-air missiles, whose hunting abilities they continue to test to the limit.

Beyond question, then, Jindivik is one of the indisputable successes of the joint project, and its most enduring technical memorial. It was the main, and arguably the only, example of the kind of full co-operation between the partners as envisaged in the initial agreement. Both countries got what they wanted. Britain got a reliable and relatively cheap target aircraft, and Australia got in addition some valuable industrial experience, so that it briefly took the world lead in the field of pilotless aircraft. It is an unfortunate but presumably unavoidable outcome of changed requirements that practically all the painfully acquired expertise of the old Target Aircraft Group at Salisbury has since been scattered to the winds.

Notes and Sources

1. At the time of the first trials (which were not secret) an argument developed over the meaning of the Aboriginal word *jindivik*. An ethnologist at the South Australian Museum said it meant not the 'hunted one' but 'to consume' or 'destroy' in the language of the Wurundjeri of Victoria.
2. Minute 137 of Board of Administration meeting No. 15 on 6 February 1947.
3. Ian Fleming, 'Thirty years later: Jindivik in retrospect'. Unpublished Sir Lawrence Wackett Lecture delivered at Melbourne in November 1977, p.3. The lecture was published under the same title in *Aerospace*, 6 (November 1979), 14-23.
4. ARC meeting No 18 of 19 October 1948.
5. During experiments in projecting fast moving objects past electronic proximity detectors there occurred the famous incident when LRWE put in an order to the toy department of an Adelaide

store for a bow and arrow.

6. Later a command-destruct system was introduced in the Jindivik and the Meteor and Canberra drones. There were several variations, but basically a radio signal to a special independently-powered receiver forced over a control surface which caused the plane to dive into the ground. Early versions of this receiver gave trouble by responding to signals on an image frequency. One engineer who monitored its output from the ground via the telemetry link was surprised to hear a message—something about the delivery of two sacks of cement—transmitted by a taxi firm in Adelaide. A simple LC filter fixed the problem.
7. This appropriate name originated during the sales drive in America, when in a Dallas bar someone started calling for 'jindiviks and tonics'. The American interest in a towed target spurred the development of Tonic. Information from Bob Leslie in a contribution of 22 August 1985.
8. Information from a member of the Jindivik Design Group, GAF, obtained in August 1976.
9. Fleming, 14.
10. Fleming, 18.
11. A. L. Vincent, 'Jindivik' Missile (December 1962), 15.
12. The overall statistics as given by Fleming for the period up to 1977 are that Jindiviks have flown on 6100 sorties and the loss rate from all causes have been about one aircraft in fifteen flights and from malfunction alone about 1:30. The loss rate was, as might be expected, highest (about 1:10) at Woomera in the 1950s, but in the last years of the joint project had reduced to about 1:85. These figures are very much better than was predicted in the early planning.

19 Processing the trials records

INTRODUCTION

A familiar aphorism of science says that only when you can measure something do you start to understand it. Of no branch of applied science is this more true than rocketry. The flight of a sophisticated guided missile may last seconds or minutes, and end in a heap of tangled wreckage. During that brief flight the interior of the missile has been a busy place indeed where several interlocking physical, chemical and electronic systems have gone flashing through a succession of transitory states. Those events must be monitored and a digest of them transmitted from the rocket. On the ground those data must be received, recorded and analysed. Then again, the missile's trajectory up to impact or to interception, if there is one, must be accurately tracked in three dimensions. Unless all these things have been achieved, the trial has been nothing but an expensive fireworks show.

We have seen earlier that Woomera had many different instruments to make all these measurements. Some of them were required immediately, at the very instant they were made, and any processing had to be done then and there. Such real-time data were mainly needed for safety surveillance, aircraft navigation and for acquisition to help other instruments find the missile. (Chapter 15 has mentioned some of the devices and displays used.) But the main purpose of the trial was not to produce data for immediate use, vital though this was to conducting the trial properly. Rather it was to make a range of detailed and accurate measurements from which the precise behaviour of the missile, aircraft or bomb under test could afterwards be computed. This chapter looks at how these millions of individual recorded measurements were processed (read, computed and the results reported) not on the spot but back at Salisbury, days or even weeks after the trial.

With every flight trial at Woomera, and at the peak there could be four or five a day, another stream of film and electronic records went flowing down to Salisbury. The films were unprocessed, and the first task was to develop and print them photographically. But then the trials measurements were still in a compressed and enigmatic form. Until the film images and tape recordings which held them had been read, the data computed and the results tabulated, they meant little. For example, the Contraves kinetheodolites exposed a series of frames on 35 millimetre cine film. Each series held images of the missile at successive instants of the flight—any frame that didn't hold an image was useless—plus a cross in the centre of the frame to show where the kinetheodolite was pointing. Also photographed automatically at the top of the frame were the settings of the instrument's elevation and azimuth scales at the instant of exposure. Unfortunately, although the kinetheodolite measured the angles with extreme precision, the figures on the scales referred to the position of the missile only if the operators were able enough to keep the image centred. Otherwise a tracking error was present, and this usually had to be calculated and corrected.[1] It was done by laboriously examining each frame through a viewer and deducing the angular displacement of the optical axis from the line of sight to the vehicle, by measuring the linear displacement of the image from the cross at the centre of the frame. The corrected elevation and azimuth angle readings were then listed for simultaneously exposed frames from this and other kinetheodolite films. (Times were synchronised to ease computation.) Having thus read or 'reduced' the data from the records, the final quantities required—trajectory in the case of kinetheodolites—were computed by triangulating corresponding elevation and azimuth angles from at least two and preferably three kinetheodolites. Since the frame times and the relative positions of the kinetheodolites were known, it was possible to tabulate the rectangular or 'cartesian' co-ordinates of the object for each time. This was the trajectory.

Radar records also provided trajectory information, but they recorded the slant range to the missile as well as elevation and azimuth. This meant that only one instrument was needed for a fix. The trajectory was computed not by triangulation but by converting from polar (elevation, azimuth, range) to rectangular (X,Y,Z) coordinates. Normally there was no correction for tracking error. Perfect tracking was assumed unless the radar had indicated a loss of lock.

The MTS records were processed in much the same way as kinetheodolites, except that, like radars, there was no tracking error correction. Doppler records were rather different. They did not measure angles or distance but changes in distance (strictly, changes in the total path length of a radio signal from the transmitter back to the receiver via the object). Thus fixes from other instruments had to be obtained and a complex calculation performed to convert the records to trajectory in the Range rectangular co-ordinate system. There were yet other types of record needing their own reading methods, and to compute all the information needed to be obtained—position, velocity and acceleration, yaw pitch and roll angles, interception miss distance and so on—usually required an integrated planned attack on a vast number of readings from many different sources.

As we will see shortly, the approach to the manifold complexities of trials data reduction and processing changed over the years. Initially it was a highly labour intensive operation using armies of young women and electromechanical calculators; but within a decade WRE had become through sheer necessity one of the pioneers in Australia of the use of modern electronic data-processing methods.

EARLY DAYS: THE 'COMPUTER GIRLS'

Judith Ellis, a Computer in Bomb Ballistics Group, uses a overhead projector to read films manually in 1949.

In the first years of the project, the instrumentation at Woomera comprised mainly Askania kinetheodolites, Vinten cameras, No. 3 Mk 7 radars, MTS and the early doppler and telemetry equipment, together with ground speed cameras at Range A. The kinetheodolites and cameras were optical instruments, so naturally they recorded on film. More surprisingly, data from the radar, MTS, doppler and telemetry systems were also recorded on film until the mid-1950s, when magnetic tape recording was introduced. (The optical instruments stuck to photography throughout the project.) Film was and still is an extremely dense medium of information storage compared with later electronic systems. But it had certain disadvantages: it was cumbersome and required quite a large staff of film processors. Even more seriously, there was no alternative at first to reading all the various squiggles of data off the film by eye. The reduction of these films—that is to say, reading the film and tabulating the data so that it could be computed—started by being an entirely manual process of which the end result was a handwritten sheet of figures to be passed on for manual calculation. The final trials analysis was presented to the customer in the form of typed tables or graphs prepared by draughtsmen. The whole procedure was extremely labour intensive.

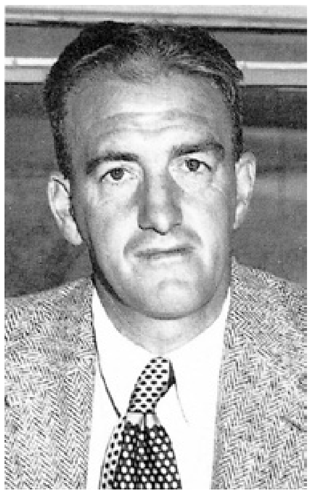
The initial activity at Woomera, the parachute trials in the southern summer of 1947, required only the simplest measurements to be taken. The first trials needing much data-processing were not rocket tests but the bomb ballistics work, which began as an extension of what the British were doing at Orfordness. The Evetts 'Bible' had already specified that 'Computers' would be used to do the data reduction and computation, just as they were used at Orfordness, Farnborough and other British establishments. The Computers in question were not of course the electronic devices familiar today but young women (a male Computer was inconceivable) mostly fresh from school. In January 1949, soon after George Hicks arrived from Orfordness to take over the newly formed Bomb Ballistics Group, the first six Computers to be recruited by LRWE joined that group. Over the next year or so the number grew to about the planned level of a dozen.

Data-processing for missile trials pursued a different course until the 1955 reorganisation, as the 'bomb' and 'missile' sides were separately organised until then. But at the beginning the missile side seemed to be lagging: at the time when Hicks secured his first six Computers not one had yet been recruited for missile work. There was a feeling back in London that LRWE might have failed to appreciate the magnitude of the processing task ahead for missile trials. One who thought so was Harry Bateman, the Assistant Director of Guided Weapons, Australian Projects, in MoS. Bateman wrote directly to Evetts in Melbourne, pulling no punches and incidentally giving a vivid if rather numbing account of the immense problems to come:

> You state in your SM1004 dated 10th February [1949] that you have sufficient computing staff, and I wish to state categorically that you have not. I feel that we are both arguing without seeing the position at the other end of the 12 000 miles, for instance I do not know how many computing staff you have, and I feel that you don't know the tremendous amount of computation necessary in Guided Weapons trials. If you agree with me that it is important that tabulated data from any particular trial is available not more than one week after that trial, the number of Computers required could be calculated if we only had a reasonable knowledge of the number of Computer hours required to perform the operation. Various figures have been given in the past for the number of Computer hours required to evaluate and analyse a kinetheodolite film of a trial; these figures vary considerably, but when it is remembered that each frame of the film has to be examined, and readings taken off of the elevation and azimuth, plus the distance from the centre of the frame in both directions, a large number of man hours is required before the actual calculation of the trajectory can be started; then as we have no elaborate machinery which will turn out the answer in five minutes, there is a tremendous amount of slogging to be done in order to get that trajectory. Again the doppler records consist at the moment of a very large number of oscillations per inch of a film running for many feet; in order to determine the velocity from this record it is necessary to count the number of these cycles between various intervals of times throughout the record. The radar tracking gear is somewhat simpler but here again a certain amount of work is required to change a record into a series of figures and from that into a trajectory. Finally there is a little matter of telemetry. Although the telemetry equipment for bomb ballistics and target aircraft is one of only five channels, that for guided missiles has twenty-four channels, and may run for half a minute or more. The information from each channel consists of a series of squiggles on a long film on which calibration marks have been made at the beginning and end, and it is a labour of love for anyone to analyse such a record. The first exercise is to measure the size of these squiggles on the film or print of film, comparing each ordinate with the calibration for that particular channel, thus giving data for the preparation of a graph or rather of twenty-four graphs. Not until then can we really see what our telemetered information is. Up to the moment Admiralty Gunnery Establishment is the only Establishment with any knowledge of the time required to analyse one telemetered record, and they give me a figure of six WAAFs, or WRNs, together with two Experimental Officers to analyse one record in one week. It is possible with experience that this time will be reduced, but I feel that I should give you all the information that I have at the moment, so that you will have a clear picture of the enormous amount of computation which will be required when the guided weapons trials are in progress.[2]

Evetts referred Bateman's gloomy appraisal to LRWE, where Frank O'Grady was in charge of recruiting all the scientific staff including the Computers, and O'Grady in turn sought comment from the trials people. Hicks, drawing on his long experience of such work at home, stuck to his earlier estimate for Bomb Ballistics Group of eight Computers in the first year and twelve in the second. He added that his estimates, and Bateman's remarks as well, assumed that no 'mechanical computers' would be available; but in fact there was already a chance that his group might get a 'suitable engine' by early 1950.[3] David Collingwood of the newly formed Test Vehicles Group estimated that ten Computers and two Experimental Officers could handle computing for the early RTV1 trials due to start later that year, 1949, but the numbers would have to be at least doubled in the following year unless good machine aids were available. Chief Superintendent Pye summed it all up by telling Evetts that Bateman was only half right: LRWE had enough Computers for the present, but would certainly need more as soon as the RTV1 trials started. He doubted whether enough could be recruited before the end of the school year, and he urged Evetts to approach the Ministry of Supply in London to see if they could offer some computing equipment.[4]

The first serious trials needing data-processing facilities were to be the 4-inch LPAA rocket trials scheduled for mid-1949. An Army signals officer, Major 'Jake' Jacoby—a tennis champion and good listener whose bellow nevertheless had a way of bringing up subordinates at the run—was asked to set up a Mathematical Services section to meet this first challenge. With great enthusiasm Jacoby collected the necessary calculators, film assessors, projectors, film reading gear and a large plotting table, and he showed great ingenuity in adapting whatever equipment lay to hand. But as Pye had predicted, getting


Major 'Jake' Jacoby, first leader of Mathematical Services section.

the trained Computers was not easy, despite some vigorous advertising. Fortunately for Jacoby a reprieve came in August when the first LPAA trials proved a flop because the instruments failed to produce any records worth reading and computing. By the time the second campaign got under way early in December, six Computers and three Experimental Officers (two of them female) had been recruited and given some training.[5] Early in 1950 numbers built up rapidly: fourteen Computers joined in February, six in March, three more in April. By now elevated to the status of a group, Maths Services with its equipment soon filled the great open upper western wing of Salisbury's Administration building. Despite all these efforts the computing of the December LPAA trials was not completed till May. But this was after all the first real test and most of the staff were still in training.

Getting the Computers at all involved something of a tussle with the bureaucracy. Earlier, one of the 'Evetts eleven', Sidney Hunwicks, who had preceded O'Grady as leader of the Scientific Staff Group, had worked energetically to establish a suitable Public Service grading for the Computers:

> In UK we had such people, mainly girls . . . who were graded as Laboratory or Scientific Assistants. Therefore we applied to Canberra for the establishment of such posts giving a job description and asked for the Laboratory Assistant scale. The reply agreed to the number of posts but said the job was equivalent only to some lower grade at Government Observatories. This we could not accept. As it happened George Hicks . . . was bringing records on which the newcomers would be trained, so we invited the Public Service Inspector to Salisbury to explain just what these people would have to do. He was convinced, so much so that on return to Canberra he wrote offering a special scale well above that of a Laboratory Assistant. Then we had to argue the other way! We managed to get sufficient for our first needs but I felt it necessary to set up good relations with the Adelaide schools so that in the future they would look on Salisbury as an outlet for their good pupils. Accordingly we arranged a series of visits to them. On the whole these went very well but one Headmistress said in no uncertain terms she was sure her girls would not be in the least interested in the work; they would much prefer the professions like banks and insurance companies.[6]

Later on, a radio advertising campaign covered the whole of Australia and the story was even picked up by the BBC world service.[7] The work became a popular choice among girls with above-average maths and physics. Despite their official grading of 'Assistant (Female) (Computing)' the Computers had a rather exciting image locally, belying the reality of what was, as Bateman had pointed out, a tedious job of reading film records and translating the multitude of squiggles into figures. But the work did have its compensations, especially the chance to take regular trips to Woomera to serve as operators of the kinetheodolites and other instruments. The mores of the day ensured that being a Computer was not seen as a very serious or permanent job, except for a few 'career' women who were regarded with a mixture of curiosity and sympathy. Computing was a fill-in job between school and marriage. The authorities expected—the Computers themselves expected—that they would soon be leaving to get married, and few of them lasted more than two years. Many of them married ex-trainees or servicemen whom they met during their Woomera visits.

The scene in Maths Services Group early in the 1950s would have presented an amusing picture to the visitor used to the video terminals and colourful electronic displays of thirty years later. The Computers had some machines to help them, but nothing very advanced. The kinetheodolite records were measured with Askania viewers; the Computers looked through eyepieces and manipulated scales to read the tracking errors. Other films were examined on a table designed for editing movie films, or were projected frame by frame. All the readings were transcribed with pencil and paper. As for the scene where the actual calculations were done, this resembled the workshop of some small cottage industry. Here the Computers sat in pairs to check each other's work, each one armed with her noisy semi-manual Friden calculator. To perform a multiplication you pressed a bar and the machine clanked round proportionally to the size of the number. You then shifted the carriage on to the next number—it was rather like operating a combination of an old-fashioned cash register and a typewriter. All the Computers grinding away together on the Fridens produced an extraordinary clattering noise. Eventually the Fridens were replaced by more modern Marchants, which were easier to use and not so noisy. But even the Marchants had nothing like the performance of a simple pocket calculator of a later era.

DEALING WITH A DELUGE OF DATA

Little of the data-processing work called for great intellectual effort, but it was very repetitive and demanded a scrupulous attention to detail. In short, it was ideal work for machines—for digital computers rather than human Computers. Here there was a difficulty. During the war the use of calculating machines and related devices had become common. Tracking radars linked to a predictor had produced a sort of electromechanical computer to aim anti-aircraft guns automatically. Analog computers to simulate missile behaviour electrically and mechanically made rapid strides in the first post-war years.[8] The thermionic valve had made realisable Charles Babbage's century-old dream of a general purpose 'calculating engine'. But when Woomera began its operations not only were computers in their infancy but even the intervening stage towards automation—the development of machines capable of reading film and putting the results on to punched cards or paper tape—had hardly started either. Electronic digital computers were barely older than the joint project itself. The very first such machine, ENIAC, only began operating at the University of Pennsylvania in 1946.[9]

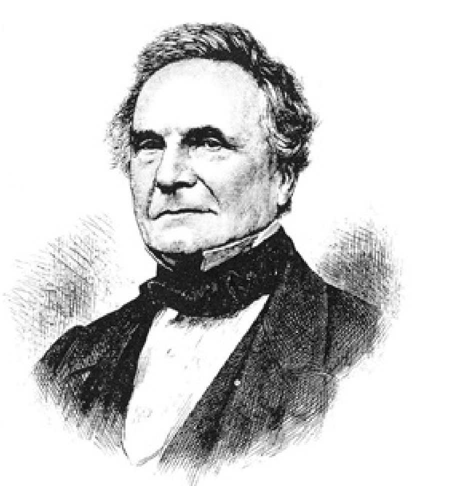
The British had taken great strides in automated code breaking during the war, and by 1949 they had a world lead in computer technology. The Cambridge Mathematical Laboratory's EDSAC, which began running in May 1949, was the first stored program electronic digital computer. But EDSAC, like all computers of that era, was the hulking curiosity of a specialised laboratory. Cumbersome, unreliable and inefficient with their thousands of valves (18 000 in the case of ENIAC), they were still in the experimental stage and it was hard to guess when they might become available even as an advanced research tool, let alone as the commonplace assistant of one's daily labours. So at least it appeared to the staff of the Guided Weapons Department of RAE, who were putting practically no effort into mechanising and automating their own data-processing tasks. Little was being done there to reduce the labour of reading kinetheodolite films; no mechanical methods were used to count doppler cycles, although a little work was being done on this; nothing was being done to speed up the reading of telemetry records. RAE efforts centred on developing the Petherick Relay Computer, the electromechanical brainchild of one of their mathematicians, E. J. Petherick of the Orfordness outstation, who earlier had designed the ground speed camera used at Woomera.[10]

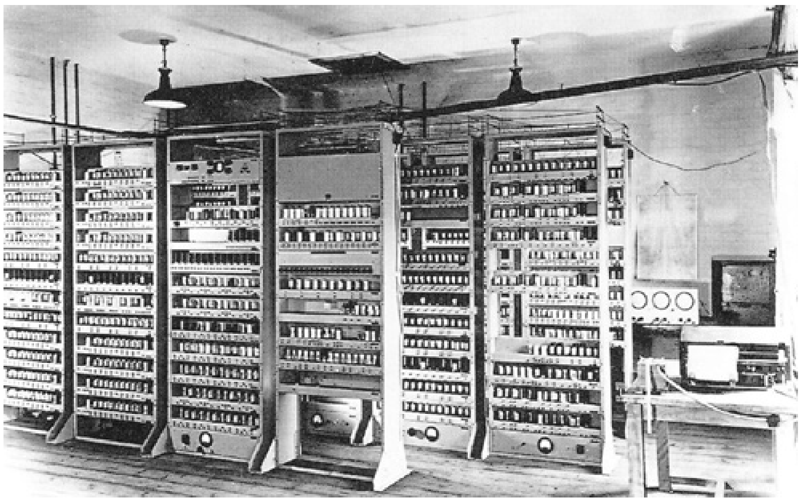
In Australia the picture looked very different. Trials were the heart of the project, and reducing trials data was enormously profligate of working time. It took, for instance, fifty hours of work to read 10 000 telemetry points from film, and another fifty hours to calculate the results with desk machines. Displaying the data and other tasks pushed the total up to 120 working hours. And 10 000 points were nothing. The RTV1 guided missile program of 1952 was to call for 19 000 telemetry points to be read for *each one* of two hundred rounds.

It is not surprising, then, that the joint project was a forcing house for computer and data-processing technologies in Australia. The first step was to buy some of the electromechanical computing equipment that was appearing on the open market in America. In 1950 some Hollerith punched card machines were ordered, of the type originally developed for sorting census records. Early the following year card punches, verifiers, tabulators and sorters were installed. Staff training began and the first data—tables of sine and cosine

Below left: Charles Babbage, (1792-1871), English mathematician. (Hulton)

Below: The Electronic Delay Storage Automatic Calculator EDSAC. (SM)





Five of the British delegates to the WRE computer conference in May 1957: (*from left*) Dr A. S. Douglas, Dr J. C. West, Dr T. Kilburn, Dr M. V. Wilkes, Mr J. H. Wilkinson.

functions—were punched. By the year's end the equipment could be used to compute and tabulate trajectories from punched cards on which the kinetheodolite or radar readings had been entered. It could do the same for velocity and acceleration from doppler readings. As more equipment, such as electric key punches, collators and a Sunstrand accounting machine, was added, the output rose. The records still had to be read and the readings punched on to cards manually, but at least the computing and tabling of results was now automatic. Only for special computations, spot checks and the like was it necessary to resort to Marchant calculators and books of trigonometric functions, logarithms and reciprocals.

The semi-automatic Holleriths were never regarded as anything more than an intermediate stage in the progress towards automatic electronic data processing. And how quickly this progress was achieved was well flagged by an event that took place in May 1957, just ten years into the project. The occasion was a computer conference, the largest yet held in Australia, and the host was WRE.[11] It was by no means a parochial affair. The computing staff of the Establishment were of course well in evidence, explaining to delegates the workings of AGWAC, the thirty-two tonne analog computer, and their pride and joy, the new WREDAC digital computer. But the conference was also well attended by academics from most Australian universities, by representatives of many public authorities, and by a sprinkling of businessmen who perhaps were there to learn how 'electronic brains' like WREDAC could be turned to commercial purposes. Luminaries from overseas were not lacking either. From Britain (courtesy of MoS's courier service) had come, among others, J. H. Wilkinson, head of the computer division of the National Physical Laboratory, and Dr M. V. Wilkes FRS, who had designed Britain's first electronic digital computer, EDSAC. But the most significant delegate from WRE's standpoint was an American, Hal Morris. Morris worked for the electronics company RCA at Patrick Airforce Base in Florida (later more familiar as Cape Canaveral). His job was Data-Processing Engineering Manager or, as the Adelaide *Advertiser* quaintly put it, 'director of the working out of US rocket test performances'.[12] To WRE his presence signalled that Australia was a few points ahead in the game of automated data analysis. Nor was this just conceit on WRE's part. It had been known for a fact since the previous September, when Boswell had led a team to inspect the American range facilities. A member of the team has since recalled:

> At the time we knew we were ahead of the British in this work because we had a lot of liaison with them. However, we suspected that the Americans with their ranges at White Sands, Point Mugu and Cape Canaveral were probably way beyond us . . . To my delight, I found that while RCA, who operated the range at Cape Canaveral, had built both Telemetry and Doppler Converters, neither worked. (To be fair, their telemetry was quite a different system from ours—FM/FM vs TDM/ FM). Bill Boswell was so pleased he dispatched Bill Watson and myself to a conference in New York held by the Instrument Society of America, which had a session scheduled on Automatic Processing of Trials Data . . . We were just in time to hear the chairman say, 'Well, we all agree that range data is a fruitful ground for automatic processing, but has anybody actually done it?' Bill nudged me, and I managed to stammer out that we had automatically processed telemetry data—in Australia. There was a stunned silence. I have wondered since whether this was disbelief—but think it might just have been that some of the audience at least didn't know where Australia was, or that we harboured such technology.[13]

WRE's achievement by 1957 was by no means insignificant. The Establishment had started well behind the Americans, and had only a fraction of the men and money at their disposal; yet it had developed and built suitable doppler and telemetry instrumentation and data converters, had linked them to a custom designed digital computer (one of only four in the whole country) and taken the lead, albeit temporary, in a difficult corner of a still arcane science.

What lay behind this success story? One vital factor was that as early as 1949 a few sharp wits had seen that the long term future of data processing in Australia must lie with automation and computerisation, and had started to plan accordingly. One of them was George Barlow, a young trainee then working on analog computing circuits with the Simulator Group in the Guided Weapons Department of RAE. One day he received a welcome reassignment;

> Late in 1949 Bill Boswell visited and said he had decided I was in the wrong place. LRWE, he said, would not be building simulators since Australia wouldn't be designing guided weapons. On the other hand the Establishment would need to process a tremendous amount of data from trials—far more than doubling or tripling 'Jacoby's girls' could cope with—and digital computers might provide the answer. . . RAE there and then released me so I could make a comprehensive tour of various firms and laboratories involved in digital computers in the UK.[14]

George Barlow.

When Barlow returned home after his British tour he found an enthusiastic ally in Jake Jacoby. As leader of the Maths Services section responsible for the flood of calculations just beginning, no one was better placed than Jacoby to grasp both the potential and the necessity of automated data-processing; but he also saw that if LRWE was to make any progress it would be entirely by its own efforts. Such was the background against which Jacoby, Barlow and a few other enthusiasts conceived LEDAC, the Long Range Weapons Electronic Digital Automatic Computer.

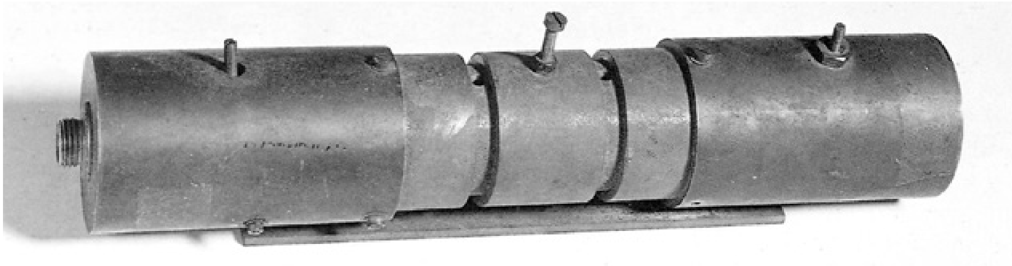
LRWE was not quite alone in these interests. There was one other place where serious work in digital and analog computing was being done in Australia. This was in Sydney at the CSIR's Mathematical Computing Machines Group, where Trevor Pearcey, under radar pioneer Dr Bowen, was designing counting units with the idea of eventually combining them into a digital computer based on the Cambridge EDSAC. (They succeeded in getting their machine, CSIRAC, to work by 1951.) Back in April 1949 O'Grady, the principal officer in charge of scientific staff recruitment, had seen what Pearcey was doing and had recommended that two of his men should be seconded to the CSIR Group to learn what they could.

Nothing came of O'Grady's suggestion, but in 1950 and 1951 there was nevertheless much liaison, both formal and informal, between LRWE and CSIRO, as it now was. At these meetings a plan for LEDAC emerged. The idea was to copy CSIRAC closely to keep the building time down, although the estimate was still two years. LEDAC should use standard components wherever possible, and should be built with ease of servicing in mind. The design should not concentrate on speed; reliability was more important, and it should have the flexibility to deal with several different tasks.

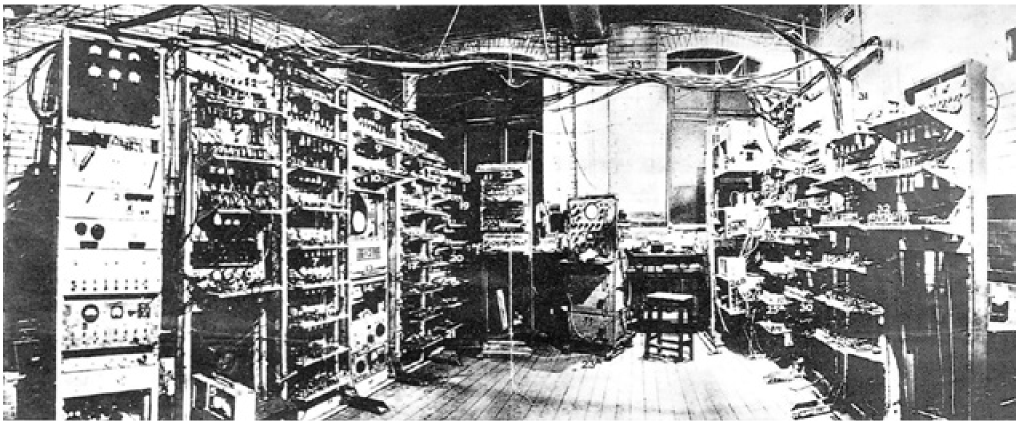
Such were the goals. Jacoby felt ready to move on LEDAC by December 1950, when he handed a formal proposal to build a computer to Boswell, then Superintendent of R&D. Dismissing RAE's Petherick machine in favour of the electronic device at least a hundred times as fast that he had in mind, Jacoby asked for £40 000: £25 000 to go to AWA for manufacturing, £10 000 to the PMG for input/output equipment, and a final £5 000 for assistance from the Engineering Department of Adelaide University or similar establishments.[15]

The year 1951 was busy indeed for the tiny LEDAC team. It consisted only of Jacoby, Barlow, and Fred Thonemann with assistance from Kevin Boyle and a former Army radar engineer, Colin Flecker. For a group of this size to take on the task of building a large computer seems preposterous today, but in fact they made quite good progress. Though the quantity of electronics was daunting enough—several thousand valves burning as much electricity as a suite of offices—many of the units were relatively simple circuits multiplied many times over, and if the project went ahead these units could be replicated in bulk by a contractor copying prototypes made in the Establishment workshops. The LRWE team had the help of Pearcey of CSIRO and the knowledge that CSIRAC, on which LEDAC was based, did actually work. LEDAC was to use a memory unit built by Thonemann, consisting of a group of sixty-four metal tubes each a metre long and filled with mercury, where the digital pulses were stored, bouncing to and fro as acoustic waves.[16] The forceful Thonemann roped in many

Fred Thonemann.



An early experimental form of the MARK 1 computer built by Manchester University and Ferranti. LRWE almost acquired one of the later commercial versions, which were much more neatly housed. (SM)



A mercury delay tube used in EDSAC. The abandoned LEDAC was to use similar but longer tubes. (SM)

different people to help with these. The Islington workshops of the South Australian Railways did the exceedingly precise machining of the tubes, and he talked the CSIRO's Division of Biochemistry into re-distilling commercial grade mercury up to the required level of purity.

In the middle of 1951 Jacoby went to a conference in Geneva and then spent a few weeks investigating the current state of British computer technology. When he arrived home and reported his findings the LEDAC team's morale soared. Few of the ten machines Jacoby had seen were at all complete, although the Ferranti at Manchester University described later was almost so. Even the Cambridge EDSAC, by now a veteran with a working life of two years behind it, still had only half its planned memory installed. In any case, one could not buy an EDSAC. It was a pure research tool made of non-standardised parts, which its designer, Maurice Wilkes, compared to an early hand built motor car. Jacoby found only one totally finished machine, a computer at Harwell, the Atomic Energy Research Establishment. That used neon Decatron counting tubes and ran at the pace, Jacoby estimated, of two experienced Computers.[17]

In September 1951 Dr Ben Gates, Deputy Chief Scientist, invited LRWE to forward a proposal to the Board for the construction or the acquisition of a computer. Gates made it plain that he was cool to the notion of constructing a machine from scratch at Salisbury, and sure enough when the Board met two months later to consider the elaborate proposal to build LEDAC it rejected it. Instead, LRWE was to get a Ferranti computer from Britain, the first commercially available stored program computer, which it could modify to suit its own needs. The order, said the Board, could be filled in only six months.[18]

The disappointed LEDAC team heard unofficially that the decision had come after strong pressure from the Ministry of Supply to place an order with Ferranti. This is very possible, as British commercial considerations not infrequently played a part in supplying equipment to the project; and in fact MoS itself bought three of the nine Ferranti machines that were eventually sold. It is equally likely, however, that the outcome had been determined several months before. In August, Howard Beale, Menzies's Minister for Supply, had taken the unusual step of attending a Board meeting. Despite the fulsome tributes Beale paid to those present, he was plainly there to foreshadow cuts in R&D spending in the next budget. Butement, as Chairman of the Board, put up a fight, saying that Australia was spending far less on military R&D than its partner, but Beale brushed the point aside. Probably LEDAC's fate was sealed at this point. Under the prevailing Dalton formula, of course, Australia would have paid for LEDAC, whereas the British would be paying for the Ferranti machine, called the MARK 1.

LRWE already knew a good deal about the MARK 1. For one thing, Ferranti had offered to sell the Establishment one some months earlier for £55 000, and had quoted a supply time of nine months. For another, it had figured largely in Jacoby's report. He had seen an almost complete version installed at Manchester University and had been impressed. He had thought the single operating console was quite a spectacular feature, and he had liked its slick and finished look. All the circuitry was hidden away neatly in metal cabinets, in pleasing contrast to the rather dishevelled appearance of the other machines. If it worked as well as Ferranti claimed, the firm certainly had a saleable product. But would it? Ferranti themselves considered its coding system unsatisfactory and were trying to simplify it. The input and output equipment had not been designed to process data on the scale of LRWE requirements, and of its reliability nothing whatever was known.

Despite all this LRWE now faced the prospect of being saddled with a MARK 1, the machine which Pearcey had colourfully described as a 'perfect "horror" to programme'.[19] But there was a reprieve. In January 1952 Board Secretary Eric Cook advised that Ferranti's quotation for a machine had soared to £95 000, with a further £90 000 for a building to house it. Chief Superintendent Pritchard thought the latter sum was far too much money, and the Board eventually deferred purchase pending reports from Butement, Boswell and R. P. Bonnell. Later in the year news came from RAE advising that the Petherick Relay Computer was being abandoned and would LRWE like to cancel its order? Of course it was eager to. The Ministry of Supply was still keen to see Salisbury pressing forward into complete computerisation, and UKMOSS was now recommending either the English Electric ACE or again the Ferranti. LRWE was now more unwilling than ever to be pushed into a computer before the time was ripe. Bonnell wrote for the Chief Superintendent cancelling the Petherick and neatly sidestepping the other suggestions by saying that the Establishment might order the Petherick Mk 2 (an electronic version at least two years away) 'in due course'.[20]

The deferral of the purchase gave LRWE scientists time to think more deeply about the problems confronting them. As they did so the realisation grew that the use of a computer, though inevitable and desirable in the long run, could not in itself solve their problems, because actual computation comprised only about a third of the total effort of data-processing. In fact for the moment the Computers could handle the calculation phase using their mechanical calculators and Hollerith punched card machines. By this time the latter had been so heavily modified that they were doing things the manufacturers never dreamed of.

The first priority was clear enough. It was to speed up the reduction phase by building or buying equipment capable of taking film records and digesting them into a machine readable form. Here was the potential for huge time and cost savings, as we can see by looking at the crucial kinetheodolite records. These were the ones which gave a precise fix on the position of the flying missile against time. The raw data from a typical trial was recorded on 35 millimetre cine film exposed in up to five Askania kinetheodolites, each running at 4 frames per second. Between thirty and sixty seconds of track might have to be analysed in detail for each record, or 600 to 1200 frames in all.[21] As the author of an RAE technical memorandum on these problems put it with British understatement in 1952, 'this multiplicity of operations with the raw records before even the correct azimuth and elevation angles are obtained must present a challenge to anyone interested in the mechanisation of data-processing'.[22] In more recent times advanced kinetheodolites have become available with automatic digital scale read-outs, and even with scanning systems to automate the tracking error determination, given suitable targets. But in the early 1950s the way forward lay in semi-automating the correction process and doing away with the error-prone hand transcription of the corrected figures.

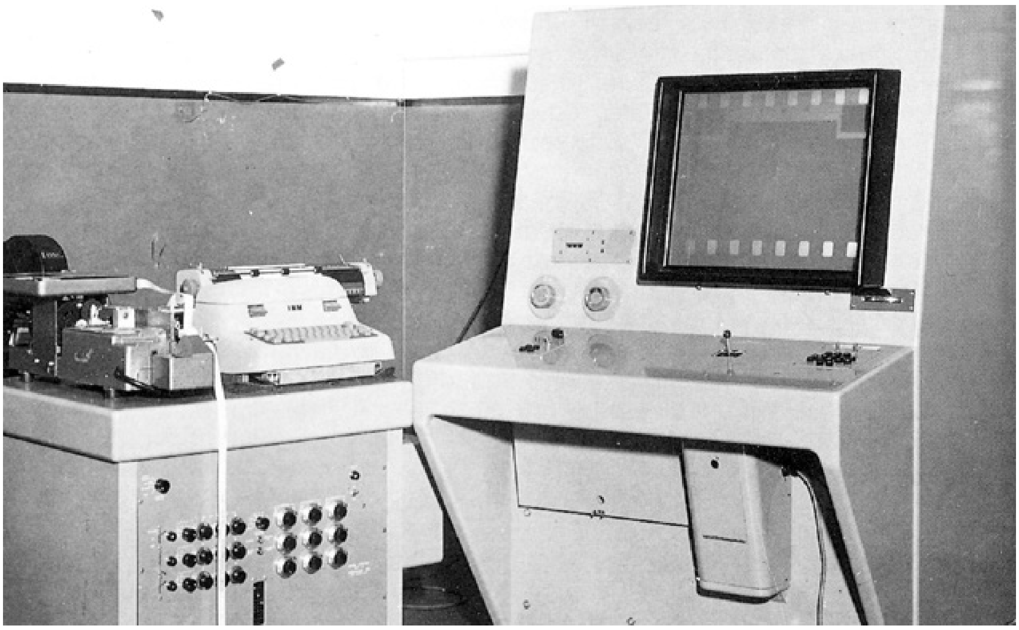
In the case of the doppler records and the telemetry records, the data came from the instruments as a frequency or mixture of frequencies, which in principle could be converted by sampling into a series of pulses and recorded on a high precision tape recorder. The specifications for such a machine exceeded what was required for even the most exacting kind of audio recording then contemplated. The signals were frequency modulated on four channels. The tape movement had to be extremely accurate, for any fluctuation in the tape speed appeared as a noise signal several times as large.

These, then, were the first steps on the road to the ideal situation where a computer took its data input in digital form, or converted it into digital form automatically; did the calculations; and then tabulated, graphed and printed the trials results for the customer. Of course it was one thing to visualise this ideal and another to realise it, but fortunately by 1952 some short cuts existed. When Boswell and Bonnell toured the US ranges late that

W. C. J. (Tim) White.

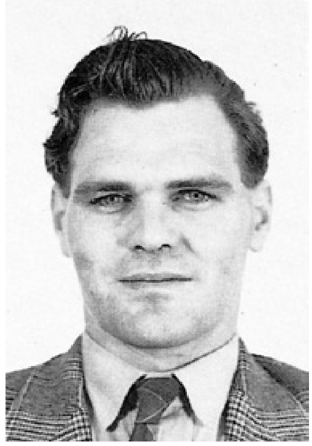
year they returned with the news that the Americans had now developed semi-automatic data-reading machines. They were commercially available, although they were not cheap. That November, Pritchard put a submission to the Board of Management for the purchase of optical readers and Ampex tape recorders costing some £63 000, most of which would be payable in scarce US dollars. It was a great deal of money for the time, and Commander Jack Newman (later a popular Range Superintendent at Woomera but then at Melbourne HQ) piloted the submission through the meeting, having asked W. C. J. (Tim) White, Principal Officer of Maths Services Group, to prepare a supplementary statement of the advantages. They were dramatic. White claimed that the equipment would at least halve the time needed to reduce the trials data from the several hundred firings scheduled for 1954, and put the results in the customers' hands that much quicker. It would also save the labour of eleven staff and twenty-one kilometres of film a year. Impressed, the Board not only approved the order but increased it by some extra machines as insurance against break-downs. Boswell was well pleased with Newman's efforts. He sent him a cryptically worded telex afterwards, 'See Daniel 5,7. And so you should.' The verse records Belshazzar's promise that the soothsayer who can interpret the writing on the wall 'shall be clothed in scarlet, and have a chain of gold about his neck': the appropriate reward in this case, Boswell felt. Newman riposted that he had hitherto looked on data reduction as being more of a Rabelaisian subject than a Biblical one.[23]

While LRWE set to work building the hardware to record and recover telemetry and doppler data electronically, in New York the Australian Consulate, which was acting as agent, started to order the optical readers, plotters and tape machines. Progress was rather slow. Many items were being made to order, and the differences in voltage and frequency of the power supplies in the two countries were awkward. New and better equipment was appearing all the time and had to be evaluated, but fortunately Jacoby was by now a Lieutenant Colonel posted to the Australian Military Mission in Washington, and both he and his superior, Brigadier Molloy, were signals officers with the skills to inspect this sort of equipment and report on it. One of their key recommendations was to buy the Boscar (Ballistic film analyser and recorder) made by the Los Angeles cybernetics company, Benson-Lehner. This machine and its later versions took the reduction of kinetheodolite film as far down the path to automation as it ever went, and were still used at DRCS well after the end of the joint project. The Boscar looked like a big amusement arcade machine, with an eye level screen and a joystick control below it. Each frame of the film could be brought up on the screen, together with its imprinted elevation and azimuth values. The operator had only to enter these values on a keyboard, centre a cross on the missile image, and press a button. The corrections to the altitude and azimuth values were at once calculated and the adjusted figures punched on to a card to feed the Hollerith machines or, later, on to a paper tape with which to feed the computer. A Boscar operator could read about three frames a minute. It wasn't fast, but it was still equivalent to the work of ten using the old manual methods.



The Benson-Lehner Boscar equipment with its decimal converter and a tape punch (1956). An Askania frame appears on the screen.

The arrival of the American equipment was only half the story. The other half belonged entirely to Salisbury. In September 1953 LRWE's Data Processing Committee met for the first time, and the next month had an important paper to consider from John Ovenstone, modestly titled 'Notes on data-processing at LRWE' and drawing together many strands in the discussions and planning which had been going on all year.[24] The twenty-one pages of Ovenstone's 'Notes' offered a broad specification for the prospective computer and for the various converters that would take recordings from the telemetry, doppler, radar and missile tracking systems and transform them into the digitised form readable by the machine. In addition, Ovenstone described the output converters which were necessary for the computer to print its results or draw its graphs. Altogether the notes comprised a bold and perceptive plan which was almost wholly realised over the next few years.



John Ovenstone, who laid down WRE's requirements for its first automatic data processing facility.

In due course a telemetry converter using about 300 valves was built to a design by Barlow, Leo Cohen of Information Studies Group and Fred Thonemann of Techniques Division. This converter and others produced input for both the first computer, WREDAC, and its successor the IBM 7090. To take the telemetry converter as an example, the process was to play the twenty-four channels of data recorded from the flying missile through the converter at one-tenth of the recorded speed. In the converter the waveform was sampled regularly and a series of digital pulses generated, the number of pulses being proportional to the strength of the sample. A marker signal of a precisely known frequency was recorded on one track so that when it and the telemetry data were compared, errors due to variation in the speed of tape transport could be eliminated. The digital code representing the values of the telemetry voltages in the original recording were transferred to a secondary tape, along with the reference frequency, which also gave a measure of elapsed time. This secondary tape, along with other similar tapes from the doppler and other converters, formed the computer input.

These advances presupposed the replacement of film by magnetic tape for all data recording except the strictly optical. The British distrusted magnetic recording and were loath to abandon the use of film for telemetry. They had a point. The telemetry signals coming from a missile in flight are often noisy and weak. A human reader could learn to discount the spikes of noise on the film record; not so a machine, which was merely counting cycles in the frequency modulated signals and could easily misinterpret the noise spikes. The British also expressed misgivings that the proposed converters and the computer would be too interdependent; that is, the failure of one part of the system would cause delays in the whole. But the Australians were set on the course which would put them well ahead of the British and ahead of the Americans by 1956. They were in a unique position. The British had a bigger labour pool to draw on, and could also get their contractors to tackle some of the data reduction, so they were not so urgently drawn to automating as fast as possible. The Americans, with their myriad contractors and their many ranges, which often had traditional service rivalries behind them, did not have the same incentive to seek standardisation. Australia was suffering from an acute shortage of labour, but it did have only one Range run by one authority, and all three services used it under civilian scientific control. The most compelling argument of all was the prospect of dealing with stupefying masses of data as the trials programs expanded over the next few years to take in the service trials of the first generation of guided weapons. In the two years 1955 and 1956 they had the prospect of reading 400 000 points of trajectory, velocity and attitude data, or about 800 points a day. In addition they would be calibrating six million telemetry points. Even at 100 per cent efficiency, this was around 200 000 manhours of work. It would take up to 200 more Computers to tackle such a load manually, from a specialised labour market already drained dry. And finally WRE would be processing as much as 600 *kilometres* of film a year!

The WRE developed telemetry (*left*) and doppler converters.

THE WREDAC ERA

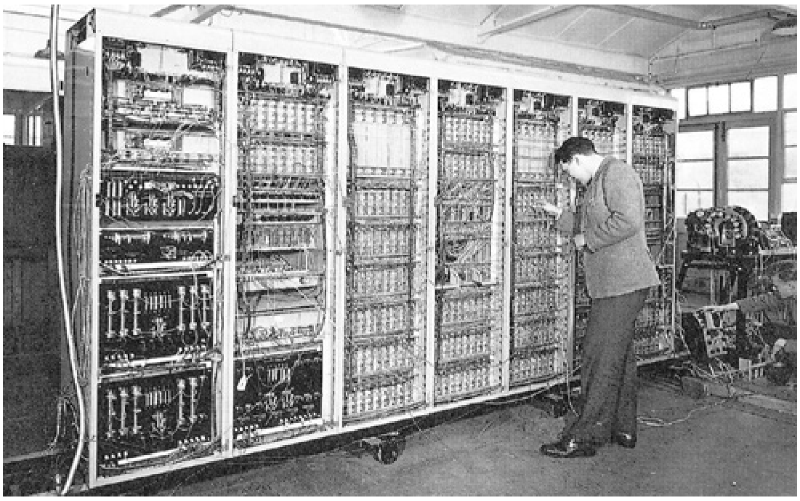
By early 1954 LRWE had given up any thought of building its own computer. Too many other tasks were now pressing for attention and LRWE now wanted a reliable, commercial machine that could go to work at once. When Headquarters offered the Establishment Pearcey's now obsolete CSIRAC, therefore, Chief Superintendent Bareford rejected it without hesitation. It was, he said, too slow and not well enough engineered; it had never passed a reliability test and was cumbersome to program. LRWE was facing a massive data reduction and processing task to meet the needs of service trials of the first generation of guided weapons. It wanted the best and most modern equipment to do it with.

Ovenstone's specification in his 'Notes' for an ideal computer were not extremely onerous. The capacity to handle input in large quantities was more important than sheer calculating power. The total storage which he saw as necessary, both internal memory and that on a magnetic drum store, was in modern terminology less than 64 kilobytes. Even so, it was by no means simply a matter of placing the order and taking delivery of a device in a crate. In the mid-1950s computer manufacture was entirely a bespoke trade, and it was impossible to buy one 'off the peg'. When the suppliers spoke of having a computer 'in commercial production' they meant they were making a few, or at most a few dozen, machines; and each one was probably being tailored to the customers' requirements during manufacture.

The specifications were circulated among interested British firms and Barlow and Ovenstone went to England in May 1954 to spend some six weeks looking at the various machines on offer. Two contenders were the English Electric DEUCE and the Ferranti MARK 1, but Barlow and Ovenstone decided both had insurmountable problems. The prototype DEUCE was barely complete and an unknown quantity; nor could a copy be built and delivered by June 1955. The Ferranti machine's neat appearance concealed the fact that it was not built out of the replaceable plug-in units that were thought essential for easy servicing. Ferranti made a valiant last ditch effort to overcome the servicing objection, but it could do nothing about the technical disadvantage that its machine stored data electrostatically, which raised questions about radio interference when there were large transmitters nearby, as at Salisbury. Eventually the contract for the supply of a 'High Speed Digital Computer No. 403 (and Ancillary Equipment)' went to the London-based firm of Elliott Bros, for a machine at a total quoted cost of £106 625. Elliott's analog computers had a good reputation, and also their 403 used nickel delay lines for the volatile memory, storing 136 pulses in each line, and so were less susceptible to electrical interference. But Elliott's secured the contract for WREDAC (originally called 'Cobber', for no obvious reason) mostly because of their low quoted price. This was divided equally between the partners under the prevailing Sandys Agreement.

Even at the time there were those who had misgivings about this decision. The knowledgeable Jacoby had strongly urged the purchase of an American computer—specifically, an IBM 701—as early as 1954, before the final commitment to WREDAC had been made. Two colleagues who accompanied him to a demonstration of the 701 in New York still recall him saying in some excitement, 'This is the machine you should be buying, not wasting your time on WREDAC. This is the machine. I know you're not listening; I know all that, but you're crazy.'[25] Probably Jacoby was correct. If a decision to purchase from IBM had been made when WREDAC was ordered, then the outcome, taking bureaucratic delays into account, would probably have been the installation of an IBM 704 capable of running the Fortran language and doing all of WRE's work for years to come. Dollar currency shortages and the political realities were against any such decision as the British fought to retain and extend their markets in the post-war period.

On 29 September 1954 the first manufacturing progress meeting for WREDAC was held at Elliott's headquarters amid a flurry of telexes querying and replying to minor details. Many things had to be settled, including questions of interfacing. Many conventions, even for instance the very basic one as to whether the pulse which represented a '1' in binary arithmetic should be positive or negative in voltage, were not then standardised. Another example was Ovenstone's suggestion of a teleprinter code in which all the numerals were represented by using only two of the five possible holes in the paper input tape. This was a good idea, because it allowed a fast visual check of the complete tape—any code with more or less than two holes could not be a number—but it was not the code Elliott's normally



Above: Part of the WREDAC computing equipment under test.

Above left: Operating the WREDAC perforated tape equipment.

used. Before a data converter being built in Australia could feed into the input terminals of a computer being built in England, all these points and many more had to be resolved.

Barlow and Ovenstone had discussed many of these matters with Andrew St Johnston and Dr Lawrence Ross of Elliott Bros during their visit, but inevitably some details had been omitted or misunderstood and many letters and telexes passed to and fro clearing up the misunderstandings. But the details which occupied the first progress meeting were more pedestrian in nature. They concerned the number of metal cabinets and their arrangement, the provision of cooling air, the determination of a work schedule to meet the tight installation date of July 1955, packing and shipping the equipment and its cost and the manufacture of the tape transport mechanisms which would be necessary to read Range data from the as yet unbuilt converters into the new computer.

The bulky WREDAC and its spares eventually arrived in Adelaide by sea in September 1955, anxiously attended by three Elliott technicians who had come to supervise its installation and put it through the acceptance trials.[26] At this time it still lacked its output converter and printer. (WREDAC did not run a printer directly. It produced an output tape which allowed it to get on with more work while the slow output devices then available printed or plotted the data.) The complete equipment filled thirty-six tall racks, half of them holding the computer itself and half the converters for telemetry, doppler and radar data. Ranged nearby were two Telereaders, two Boscars, an Oscar and a kine reader. The film readers originally produced punched cards for feeding into the Holleriths, but WREDAC could not read cards, only paper tape. Attached to the film readers, therefore, were Creed teleprinters and tape perforators to produce the input tape that WREDAC could handle.

The computer's permanent disk memory was a physically impressive feature. It was nothing like the small sealed hard disk units of the 1980s which read and write megabytes of data with minimal maintenance. This disk was a platter, 46 centimetres in diameter, sitting inside a large cabinet with double doors. Above it was a mass of eighty individually adjustable pick-up heads, each of which had to be set just one-fiftieth of a millimetre above the surface—too close, and the disk would be scratched; too distant and the head did not receive enough signal. (If the disk did get scratched, though, a head could simply be moved across the disk to find an undamaged spot.) Even while the disk was stationary, a constant flow of warm oil bathed the bearings to avoid any rough starting which might cause the heads to score the delicate oxide surface. Like all computers of its day WREDAC was far from being, as the jargon has it, 'user friendly'. Quite the reverse. It needed constant attention from operators who knew exactly how to get the results they wanted, as well as a team of maintenance staff to fix it each time an error occurred in the calculation sequence.

A year passed before WREDAC ran properly. Despite the installation team leader's confident assertion on his return to England in November 1955 that 'when he left the actual commissioning was effectively over'[27], six more months passed before the two remaining Elliott technicians at Salisbury even attempted to run the acceptance tests. There were many problems. Not for the first or last time, equipment designed in temperate climates worked less than successfully in Australia. Ambient temperatures in the mid-30s that summer played havoc with the electronic circuitry, which itself produced many kilowatts of waste heat to be disposed of by uncertain air-conditioning. Some problems certainly arose from faulty design. In the circuitry which fed the delay line memory, the valves specified, 12AT7 double triodes, were being driven much too close to their performance limits. After a few hundred hours the normal slight decline in the electron emissivity of their cathodes, which would have been inconsequential in any other application, started to corrupt the data passing through them. A good quarter of the 500 valves in question had been replaced by mid-February. Ovenstone wanted a better valve with a firm guarantee of a two-year life, but he never got it. The life of a valve in the demanding memory driver circuits was always relatively short, although eventually the maintenance engineers worked their way round the difficulty by screening the performance of new ones and putting only the 'pedigree' valves in the most exigent positions.

In the time-honoured way, supplier and customer tended to blame each other for WREDAC's teething troubles. WRE criticised the poor standard of workmanship, while Elliott accused the Salisbury engineers of fiddling with precision equipment without knowing what they were doing. In a generous move Elliott eventually replaced the entire disk unit at no charge, but this cut no ice at WRE, where the firm's performance in rectifying the faults was later judged to have been 'something less than spectacular'.[28] A more balanced judgment should stress that everyone at the time was down near the bottom of the learning curve when it came to computers. Elliott's Computer Division was desperately overloaded with orders. While trying to fill the order from WRE it was simultaneously building a similar machine for the Pascal Institute in Paris and another for exhibition. The Division moved to a new site in the middle of the Australian job, and the whole firm was short of trained and skilled staff. It was only in June 1955 that the company, responding to strong pressure from WRE to meet its schedule, first resorted to shift work. Even then the testing was cut short, but WRE mistakenly thought this was better done at Salisbury in any case.

At the end of the December 1956 quarter Ovenstone said optimistically:

> For the first time since the Range commenced operation there was no backlog of trial calculation over the Christmas period and, despite the shortage of skilled programming and maintenance staff, a reasonable service to the establishment was maintained.[29]

Ovenstone predicted that WREDAC would soon be working for eight hours of a ten-hour day. Although this was not an unreasonable assumption judging by other computer users' experience, it proved to be far too optimistic because for a time WREDAC got worse, not better. One problem was the change-over from punched cards to the paper tape handled by WREDAC. American computers and data-processing machines at the time used punched cards, because they had evolved from business machines which also used them. British computers stored their data on cheap paper tape, because they had come out of university laboratories which were used to working with readily available telegraphic punched tape machines. The American film readers originally produced punched cards, but had been modified in Australia to use tape when WREDAC was introduced. This was a handicap, because the operators found that an error which previously had been easy to correct by punching a new card and throwing away the old one was much more troublesome when a whole new tape had to be punched instead. For this and other reasons WREDAC had a rather feeble performance even compared to much slower machines. Just before the computer symposium at WRE in 1957 H. L. Barman of Rolls-Royce wrote to Director H. J. Brown asking for details of WREDAC's performance so that he could compare them with his firm's IBM 650, a machine with a drum memory that was much slower than WREDAC. He mentioned that they were getting 134 hours of useful output per week with an hour a day scheduled for maintenance and an average of 34 minutes a week breakdown, which gave them an overall efficiency of 99.6 per cent. The comparison with WREDAC was embarrassing then and would become more so. Even two years later, in 1959, the machine was providing only about 30 hours a week of useful computing time, and half of that was absorbed by program testing and other work.

Eventually WREDAC was made to work with reasonable reliability. Colour-coded cable gradually replaced the tangle of white wiring. Elliott had used single strand wire to connect the plug-in units and when it broke, as it sometimes did, it was almost impossible to find where it was meant to go. WRE staff added extra circuitry and finally put the power supplies out on the veranda of the building—something they had wanted to do from the beginning. This reduced some of the heat load and better air-conditioning coped with the rest. A report published in early 1959 said rather defensively that despite its limited hours WREDAC was processing very much more data than had been handled before its introduction.[30] This was true: depending on how the calculation was done, up to ten times as many data points were being produced. One reason why WREDAC did not make a better showing was that the demand for computational services had risen so much that it cancelled out the gains. An embattled Maths Services Group were constantly under fire from other Divisions of WRE, particularly Systems Assessment (SAD) and Aerodynamics (AD). In using computers it is very much the case that the appetite grows by what it feeds on. SAD had developed an elaborate technique whereby it took the measurements of the actual flight trials at Woomera of the new guided weapons Red Duster and Red Shoes in digital form, and then had the data converted to analog form to serve as input for their laboratory simulators. This process used up machine time at a fearful rate and was always urgent. The complaint of people working in AD was that their work did not carry the same urgent priority of much of the missile trials work, so that often they found themselves well back in the queue. Maths Services tried to shift the load by pushing the Red Duster data conversion work back on the contractor, Bristol Aeroplane in England, and by analysing only the most critical parts of each trials record. Certainly there was little hope of improving the rate of output. By 1959 the WREDAC staff were already working two or three shifts plus some overtime in an attempt to catch up, but this was producing labour problems. WRE could order its employees to do shift work and, while junior staff were obliged to accept it, the senior staff (who had to be on duty as well, to solve WREDAC's problems) did not take kindly to being employed, as Ovenstone put it, 'all night and morning on work of a not very inspiring type'.[31] In 1958 well-trained computer staff were at a premium in Australia, and there were plenty of vacancies for research programmers in Sydney and Melbourne at comparable salaries. Ovenstone himself left to take a senior position with the Department of Defence to establish their data-processing system. A mild state of warfare broke out between the two departments of Supply and Defence as Ovenstone went on to poach as many of the more senior and capable computer scientists as he could. By early 1959 there had been an alarming number of resignations. To stay at WRE meant staying with WREDAC, something that offered little chance of professional advancement given the machine's obvious limitations. WRE could not abandon the machine so soon after installation, but trying to keep it running was not a prospect to inspire any bright young man with a career to build.

There were problems, too, among the more junior staff, most of whom were women. For them there were only two grades, Assistant Computer or Senior Computer, and although the wages were good for juniors there was no career structure for those who were looking for further promotion. Not that WRE could offer much inducement for its Computers to see their work as a career. Public Service rules made resignation mandatory on marriage, and although re-employment as a temporary worker was possible or even probable afterwards, it was not guaranteed. The private firms on the Salisbury site placed no barriers in the way of married women and were willing to pay more than the government rate for a skilled computing assistant. Such policies cost WRE dearly in checking and rereading faulty work. One estimate is that every kinetheodolite point was calculated twice and every piece of telemetry data perhaps three times, partly from the need to correct processing mistakes by inexperienced staff working under pressure.[32]

In November 1960 Trials Superintendent J. Clegg was able to report at last that the reliability of WREDAC had risen above the 80 per cent mark. By then, though, the statistic was of little moment. WREDAC was thoroughly obsolete and WRE had ordered its successor.

WREDAC REPLACED

It had become obvious by mid-1959 that WRE could not delay much longer in ordering a replacement, even though WREDAC had given less than four years' service and, with its accompanying output converters, printers, plotters and additional tape machines, had cost the partners about £300 000. The final impetus for a new purchase came from the forecasts of the work that would result once the continent spanning flights began in 1960 of the intermediate range ballistic missile, Blue Streak. These trials were expected to continue for years on a grand scale. To give only one example of the work they would generate, the powerful ballistic cameras which were to record the payload's re-entry into the atmosphere had to be calibrated regularly against a star background, much as the ground speed cameras had been calibrated in the early days of the bombing range. There were to be up to fifty of these cameras. Checking just one ballistic camera would take three hours of WREDAC computing time, provided there were no data or machine faults. This never happened: WREDAC's 'mean free error path' lasted fifteen minutes. Even allowing for the spasmodic nature of trials work, the immediate future called for a computer with twenty times WREDAC's capacity.

In March 1959 the difficult decision on the type of machine to be purchased was put in the hands of the Data Processing Committee. Barlow, who had become the first civilian to fill the position of Defence R&D Representative in the United States, forwarded details of some suitable American machines. He enclosed brochures for the Univac Scientific, the Honeywell 800, the Philco Transac 2000 and the new transistorised IBM 7090, the first model of which was due to be delivered to the Vanguard Computing Center early in 1960. The 7090 cost over $US3 million, but IBM already had many government orders for it. One group alone had ordered seven.

Certainly there were many different opinions to canvass, since everyone was most eager to learn from experience. Bill Watson, Acting Superintendent SAD, spoke for everyone when he insisted that 'the opinion of several experts is needed—if only to ensure we do not buy a "bunny" '. Watson emphasised the need to bear in mind the needs of users other than the trials staff. Digital simulations of missile behaviour, which would eventually render most analog techniques obsolete, were then on the horizon. Buying the right digital machine could mean that the services would need only 'one digital machine which could do sums on all weapons, instead of having an analog machine for each weapon.' Watson also wondered whether some of the strain could be taken off WREDAC. The calibration of telemetry, for instance, was done on the computer, which for Watson was like 'using a stone crusher to break a peanut.' Perhaps the replacement of WREDAC could be deferred by purchasing some specialised equipment.[33]

This suggestion gained no support, but one thing which did unite all opinion at WRE was that the Establishment should give up thermionic valves and go for one of the latest generation of solid-state machines using individual transistors. There was only one British transistorised computer in the offing, the EMIDEC 2400. It was not a strong contender. It had a comparatively small memory and was only about eight times as fast as WREDAC. It used an inordinate 35 kilowatts of power and hence would have needed almost twice as much cooling as WREDAC. Worst of all, from the WRE point of view, it was only a prototype which was unlikely to be finished before 1962. The political pressure to buy British had abated since WREDAC had been bought, for by this date even MoS establishments like Aldermaston had either bought or were looking at American computers.[34] Of the two American machines then available that met WRE requirements, the IBM 7090 and the Philco Transac 2000, the former was judged the better, especially because a large library of programs was available for it. Experience with the bespoke WREDAC had shown the high cost of having to write software for oneself for every new problem. The value of having access to a large library of programs was obvious and a purchase of the IBM 7090 would give that, since the introduction of the Fortran language allowed program code written for earlier valve machines to be recompiled and run on the

The IBM 7090 computer installed at WRE.

transistor one.

At the Board of Management meeting of 8 March 1960 the vote was to hire the 7090 for $US330 000 a year with an option to buy after the first year. The order went straight to IBM just five weeks before Blue Streak was cancelled. Two WRE scientists, Peter Goddard and Barry McDowall, went to the States to learn how to program the 7090. The first reports were not too favourable, but IBM, unlike Elliott a few years before, had the production capacity and the engineers to remove the gremlins intrinsic to any new design. The 7090 was delivered to WRE at the end of 1960 and officially handed over to the Minister for Supply, Alan Hulme, on 13 February 1961.

Peter Goddard of Maths Services Group. Later he became the head of its successor, Computing Services Group.

Some fifty people applied to attend the Fortran course held before the new machine was installed. WRE also joined SHARE, one of the first user groups established by aerospace programmers in California, and started to receive programs from many other US sources. This presaged a change in the use of the computer. Formerly programming had been the preserve of a few initiates who could cope with WREDAC's peculiarities, and they tended to have a rather proprietorial attitude to it. R. G. Keats of Systems Assessment Division (SAD) was one of those who argued for more general access to the new machine. As mentioned earlier, SAD had been a persistent critic of Maths Services Group, and SAD could not be ignored as its modelling work was of growing significance in the economical production of new weapons systems. After some resistance Keats got his way and WRE started to allow its individual engineers to write the code for their own task and submit it to the data-processing office for running. SAD benefited greatly from the change, becoming a major user of the new machine to the extent of some 400 hours a month of central processor time. Maths Services still provided expert advice and assistance; it did not attempt to provide a general programming service. Other groups were happy to leave the entire business of writing programs and running them to the data-processing department.

The method of handling the Range data did not change much with the new machine but followed the pattern established in the early years of Woomera. Work was still handled in batches as it had been with WREDAC but with greater efficiency and smoothness. The replacement first of paper tape, and then punched cards, by magnetic tape was the chief cause. Film and magnetic tapes from Woomera passed through a records office whence they were sent to various sections, one for each project. There, under the direction of a mathematician, a team of Computers would assess the quality of the films and tapes and decide which parts were to be processed. The kinetheodolite films were read on the Boscars and converted to punched cards, then the data from one kinetheodolite was merged with that from another and differenced in a 407 Accounting machine. The results were tabulated for checking and, when all visible errors had been eliminated, the cards were sent to the computer with a request for a trajectory calculation. Other film records were reduced on a Telereader, a general purpose film reader which could also measure angles.

These machines and the new computer allowed a great expansion in data-processing capability, as the following table shows:

Comparative Loads and Costs

	Trajectory points calculated per day	Cost of each calculated point
1955-56 (pre-WREDAC)	800	$A4.00
1956-57 (WREDAC)	1000	50c
1963-64 (IBM 7090)	3000	10c

To make the whole system as reliable as possible throughout, it was advantageous to upgrade the data converters as soon as possible. Computer Electronics (CE) Group, then under the direction of Barlow who had returned from his American posting, was given the job of rebuilding the converters and making them compatible with new telemetry systems then being introduced. The circuitry was transistorised and built on small printed circuit boards. Some of the boards in the new doppler converter, the last completed, used resistor/transistor logic microcircuits which were the forerunners of integrated circuits and were then becoming just cheap enough to compete with discrete transistor circuits. CE Group also revamped the sturdy Ampex FR400 tape recorders which had begun their life attached to WREDAC, by fitting a vacuum tape chamber and new digital electronics to increase their data capacity from 200 bits/inch to 600 bits/inch. It is a tribute to the workmanship of both the tape machines and the converters that they were still attached to the computer system in 1986. But by then little of the data they converted was coming from Woomera.

WREDAC continued to run in parallel with the IBM 7090 for a time, but as its programs were converted to run on the newer machine it became more and more redundant. Its attendant maintenance staff were expensive, and at the end of 1962 Barlow recommended that WREDAC should be disposed of. He suggested that rather than being broken up it might be offered free to the South Australian Institute of Technology. Others more cynical or more realistic correctly averred that no one could afford to take on WREDAC even as a gift. Its ultimate fate is hazy. A few parts did go back to Britain as spares, but most of it probably ended as scrap. The electronics revolution had taken WREDAC from being the *dernier cri* in data-processing to the junk heap in less than a decade.

LATER COMPUTING FACILITIES

The excellent reliability and much greater speed of the new IBM 7090 helped the growth of programming skills within WRE. When Blue Streak was cancelled, spare capacity became available for less than urgent tasks for the first time since the arrival of WREDAC. Then, too, the specialised programs available from other ranges that were able to run on the 7090 meant that the mathematicians could handle much more complex tasks than ever before. The new computer played an important role in WRE's support of the American space programs, and it was vital to the success of the ambitious ELDO firings of the mid-1960s. Knowledge too had increased, as Mary Whitehead found on one visit to the United States. For some time she and others in Maths Services had been puzzled by a tiny but persistent bias in calculating those missile trajectories that were based on observations taken from two Range posts distant from one another. The surveyors had checked their measurements and had found no significant errors. The reason for the bias was known in America, where at the time it was a classified secret. As a missile flies over terrain even as flat as that of Central Australia, the pull of gravity on it fluctuates slightly as though it were flying over mountains and valleys. The roots of ancient mountains, long since worn level, are denser than other rock and cause variations in the gravitational field through which the missile is flying. Its trajectory therefore differs minutely from that predicted when the international spheroid model of the earth is assumed. After the variations on the Woomera Range had been measured in a special survey and incorporated into a sophisticated program for the 7090, it proved possible to fix the position of a flashing light on a Black Knight rocket to within a radius of 6 metres while it was more than 320 kilometres above the earth.

An IBM 1401 processor was added to the system in November 1962 to control the input and output functions, and that year WRE decided to buy the 7090 equipment outright. The decision made good sense at the time because it appeared to save money, but in retrospect it was a mistake. WRE found out, as had other users, that computer use was doubling every two years and the 7090 quickly became outdated. Like WREDAC before it, it was soon working shifts and turning away all outside work. But shift work did not cause the same problems as it had during WREDAC's day, as the 7090 did not need anything like the same amount of skilled supervision.

The 7090 remained in operation until 1976, although in September 1975 it was effectively superseded by a new IBM 370/168 which was temporarily installed in a building in the Contractors' Area. Computing Services Group, as it had become by then, ran both machines in tandem while a building in the Laboratories Area was extended to take the 370. The new machine was installed in the second quarter of 1976 and, after another three months of parallel running, the 7090 was switched off for good. During the change-over period Planning and Data Analysis Group (one of the remnants of Trials Wing) transferred their Range data processing programs to the new machine. The computer was upgraded continually (to a 3033 CPU in August 1978), but by 1980 trials data processing from Woomera had sunk from being the sole employment of many hundreds of people to one of the more trivial of its tasks.

Notes and Sources

1. Tracking error corrections were not invariably performed. Sometimes great accuracy was unnecessary, or a skilled Contraves operator might introduce only a negligible tracking error.
2. Quoted in a Ministry of Supply Minute 'Staffing LRWE'. File SA5041 folio 29A.
3. Note from G. E. Hicks. File SA5041 folio 30A.
4. Notes from D. G. Collingwood and R. W. Pye. File SA5041, folios 34A and 37A.
5. Drawn from the recollection of Mary Evans, who was one of the Experimental Officers. Recruited to the project in October 1949, she spent much of her subsequent career at Salisbury.
6. Contribution from S. A. Hunwicks in 1980.
7. Reminiscence of Mary Whitehead at the Computers' Reunion of 29 August 1983.
8. Analog computers work by measuring changes in magnitude of some quantity such as electrical voltage; digital computers by counting electrical pulses. At the time under discussion, analog computers were by far the more common; for example in automatic aircraft navigation systems. Except in a few highly specialised applications, they are now obsolete.
9. Claims have been made for the priority of COLOSSUS, an electronic code breaking machine which became operational at Bletchley Park in England in December 1943. However, COLOSSUS was externally programmed: it did not have a memory where binary digits could be stored and retrieved at high speed. Nor did the Pennsylvania EN1AC. The Cambridge EDSAC was the first electronic stored program digital computer to operate (in May 1949) and has the best claim to being the world's first 'true' computer.
10. See 'The Shopping List for Australia, 1947-48', Chapter 10.
11. Although not advertised as such, this meeting was the forerunner of the first official National Computer Conference of 1960. The success of the 1957 meeting was largely due to the efforts of John Ovenstone (or Allen-Ovenstone). He joined LRWE late in 1950 and while taking a doctorate at Cambridge became interested in the potential of digital computing. An important pioneer in this field, Ovenstone was the first Professor of Computing Science at the University of Adelaide. He died in July 1984.
12. 'SA talks on automation', *The Advertiser*, 30 May 1957.
13. Contribution from G. E. Barlow in July 1984.
14. Barlow.
15. Draft report 'Construction of an electronic digital automatic computer at LRWE'. File A427/1 folio 76R.
16. The mercury tank memory had been invented at Cambridge in the winter of 1946 by Wilkes and a Cavendish laboratory research student, T. Gold, and was used in EDSAC. By 1951 when LEDAC was being designed the system was virtually obsolete, but it did have the advantage of being tried and tested. See Maurice V. Wilkes, *Memoirs of a Computer Pioneer*, MIT Press, London, 1985.
17. 'Report on automatic computing machines in UK (August 1951)'. File A427, folio 54B. In it Jacoby said, 'The Harwell computer is completed. It may truthfully be said that this is the only completed computer in UK which is operating as planned.' Jacoby also saw a machine called LEO (Lyons Electronic Office), memorable as the first business digital computer. It is curious that Jacoby did not give more attention to LEO. It was based on EDSAC, the only computer with any significant performance history; it was complete, installed, and about to start testing; and it matched LRWE requirements of a modest calculating power but a large input capacity. Possibly Jacoby was not an entirely disinterested reporter, as he was committed to LEDAC.
18. Memo dated 12 November 1951 from R&D Branch Secretary to Superintendent LRWE. File A427/1, folio 68A.
19. Letter dated 7 December 1951 from T. Pearcey to R. W. Boswell. File A427.
20. Letter dated 16 January 1953 from R. P. Bonnell to Controller R&D Melbourne. File A427/2 Part 1, folio 23A.
21. The trial reading workload increased markedly after the Contraves kinetheodolites were introduced in 1955, as they normally recorded at 20 frames per second. By 1962 fifteen were installed on the Range and between them a total of 90 000 frames could theoretically be recorded on a trial. In practice only about 3500 of them would be read for a typical long range interception trial.
22. C. E. Kerr, 'Present prospects for the mechanisation of trials data processing'. RAE Technical Memorandum GW 159 dated January 1952. File A427/2 part 1, folio 3C.
23. Teletype dated 10 December 1952 from Boswell to Newman; teletype dated 1 December 1952 from Newman to Boswell. File A427/2 part 1, folios 14A, 15A.
24. J. Allen-Ovenstone, 'Notes on data-processing at LRWE' dated 9 October 1953. File A427/2/2, folio 7A.
25. Reminiscence of P. N. L. Goddard at an interview of 3 July 1985. W. C. J. White, also present at the demonstration, heard Jacoby's assessment. Information in a letter of 15 February 1986.
26. It is an interesting commentary on the Australian electronics industry at the time that apart

from the valves and some crystals all the spare parts for WREDAC, right down to sets of resistors, were imported with the machine on the grounds that supplies might not be available locally.

27. Minutes of the 12th Progress Meeting held at Elliott's, Borehamwood, UK on 29 November 1955. File A427/5 part 2, folio 223.
28. Memo dated 5 June 1962 from Principal Officer Maths Services. File SA5398/11/2.
29. J. Allen-Ovenstone, 'WREDAC quarterly report 1.10.56 to 20.12.56'. File SA5398/11/2.
30. W. C. J. White, D. L. Overheu, & J. N. Weadon, 'A report on data processing at WRE'. Technical Note TRD 2. Overheu has since noted that not only was WREDAC not able to do the work for which it had been bought but staff were asked to use it to do work for which it was not intended and, although reliability had been improved and its capacity extended, WREDAC had been taken to its limit by the time of its replacement. Information in a letter of 30 January 1986.
31. Memo 'Shift work on WREDAC' dated 18 February 1958 from J. A. Ovenstone. File SA5 398/11/2.
32. Goddard.
33. Minute 'The new digital computer' dated 22 April 1959 from Acting Superintendent SAD W. R. Watson. File SA5398/3/1. The analog computers consisted of components—amplifiers, multipliers, servo units—that could be connected up to simulate various systems. However, building up a large system took a long time and naturally people were reluctant to dismantle it if it might be needed again.
34. Minutes of a meeting between a WRE party and the computing staff of the Atomic Weapons Research Establishment Aldermaston on 3 June 1959. White and Overheu were told that, even if a fast enough machine was available in the UK, AWRE would not buy it because program backing would not be available. File SA5398/1/1 part 1.

20 High flyers

THE SOUNDING ROCKET AND THE UPPER ATMOSPHERE

One of the major events of the 1950s was the International Geophysical Year (actually 'Year-and-a-half', for it ran from 1 July 1957 until 31 December 1958). This was a global effort of scientific research in which seventy nations and tens of thousands of scientists participated. The most spectacular achievement was of course the launchings of the first earth satellites. President Eisenhower announced in 1955 that orbiting a satellite would be part of America's contribution to the International Geophysical Year, and the Soviet Union made the same pledge in September 1956. Before the Year was four months old the USSR had put Sputnik 1 into orbit (on 4 October 1957) and the US followed suit with Explorer 1 on 31 January 1958.

These spectacular and familiar achievements have overshadowed the more sober research efforts of the Year, which were notable enough in their own right. They centred on investigations into the large physical forces which affect the earth, and the most relevant disciplines were therefore astronomy, geophysics and meteorology. Some of the specific subjects of study were the polar regions, particularly Antarctica; ways of making more exact determinations of longitude and latitude; and investigating the phenomena of the upper atmosphere. The timing of the International Geophysical Year was planned to coincide with a period of maximum sunspot activity, which occurs in regular cycles of eleven years.

By the early 1950s sounding rockets had become a valuable tool for research into the higher atmosphere. The observations one can make with rockets are limited in duration, but they are much cheaper and simpler to use than satellites (which were not available anyway in the earlier years), and they can be launched wherever and whenever convenience dictates.

Another advantage of sounding rockets is that they alone can take instruments into the lower ionosphere, the region from 80 to 160 kilometres above the earth. This part of the ionosphere is higher than balloon or aircraft can reach, and lower than an orbiting satellite can descend because of air drag. And it is a region where much is going on—interactions between the earth's atmosphere and solar ultraviolet radiation, terrestrial magnetism, micrometeorites, cosmic rays—all of which repay scientific investigation. Until quite recently the properties of the ionosphere were largely a mystery to physics. Visible events such as the auroras and shooting stars had long been known, of course; and radio physicists had deduced the existence of electrically conducting layers at heights of 60 kilometres and beyond, because they absorb and reflect radio waves, making it possible for them to travel round the earth. These physicists had noted that the distance and proportional size of these layers varied with sunspot activity and magnetic storms emanating from the sun. But the composition of the upper atmosphere, its ability to absorb radiation, its winds, density, temperature and the variations of these properties with changes of height, were among the things about which physicists and meteorologists wanted to learn more, if only to understand and predict their effect on events closer to the earth's surface. This interest was not solely one of pure science. For example, the fierce solar radiation converts some of the oxygen into a chemically distinct form, ozone, which protects organisms on the land below from the lethal effects of that same radiation. It was known that the ozone layer varies under seasonal, geographical and temporal influences; but much remained (and remains, for that matter) to be discovered about the reasons for these changes.

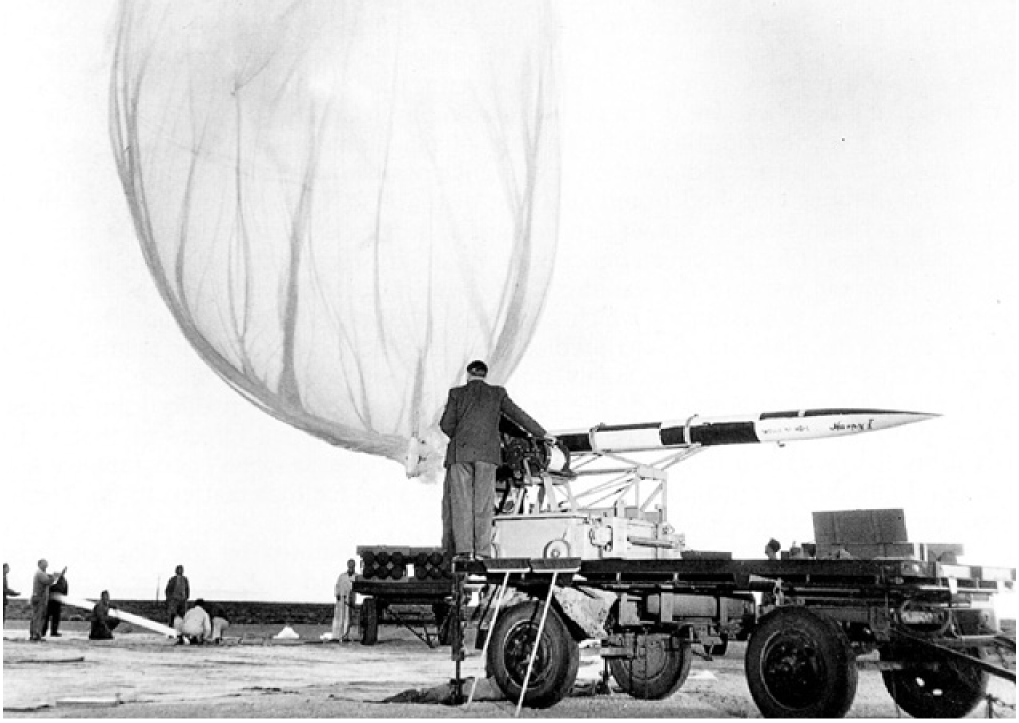
Early atmospheric research in Britain was co-ordinated by the Gassiot Committee of the Royal Society.[1] In 1954 the Committee asked RAE to assist in building a rocket capable of carrying a 100 kilogram payload up to an altitude of 100 kilometres, with which to investigate the upper atmosphere during the International Geophysical Year as part of Britain's contribution to it. The RAE thereupon began the development of a new high altitude sounding rocket called CTV5 series III, initially by extending the existing Control Test Vehicle program as described in Chapter 11.

The long trajectory of the rocket and the need to recover instrumentation packages from the ground dictated the use of Woomera. The proposals were put to Australia at the CUKAC meeting of August 1955, and were accepted as items under the joint project by the following June. The initial intention, expressed in the planning specifications, was to include tests of ballistic missile components in the trials objectives, but this rarely occurred and was later deleted.

CTV5 series III under its new name, Skylark, fulfilled its Gassiot objectives during the International Geophysical Year and subsequently continued with its scientific program to become Woomera's longest running project. More than 250 Skylarks took to the air over twenty years, carrying many different experimental packages into the upper atmosphere for universities and research institutions. Skylark's performance was progressively improved, and its observations extended to cover astrophysical measurements of the sun and the stars. In its final years Skylark was used to photograph the earth from high altitude, in a resource assessment program.

Australia started to plan its own national contribution to the Year as early as 1955 with the development at WRE of a high-altitude research vehicle, Project HARP. A sounding rocket was to carry aloft instruments to measure atmospheric conditions and wind velocities during the almost vertical ascent to 100 kilometres. HARP's unconventional feature was that the rocket was to be lifted by a hydrogen balloon to a height of about 12 kilometres before being aimed upwards and fired by radio command. Such 'rockoons' were not new; they had been used by others, including Van Allen, after whom the radiation belts encircling the earth are named. Rockoons enjoyed the advantage of getting a free lift into the thinner air of the upper atmosphere, so reducing drag and getting better performance out of a small motor. The gain was considerable, for the HARP rocket launched from the ground would barely have reached 24 kilometres.

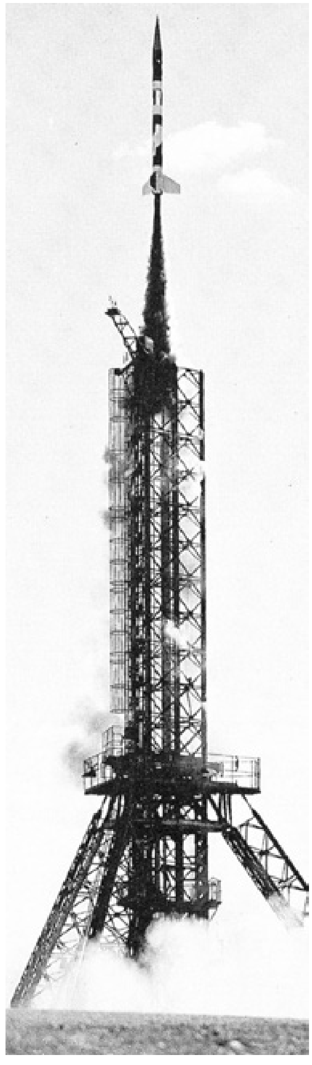
The HARP rocket weighed 270 kilograms with its payload and a huge balloon, 18 metres across and 30 metres high when inflated, was necessary to lift it. Early in 1957 all was ready. Trials began using a dummy payload and, while some were successful, the balloon proved tricky to handle. Random wind gusts are common at Woomera even during the calm early morning hours. Some gusts were strong enough to damage the fabric of the balloon as it filled, and no satisfactory sheltered area could be found. Bristol University made the balloons and, after one of its staff had paid an advisory visit, the conclusion was that Woomera was no place for rockoons if the rockets had to be fired to a timetable. So HARP was abandoned early in 1958.



An early HARP trial.

Fortunately HARP was only one item in WRE's long involvement with the upper atmosphere. HARP had been handled by two divisions, Propulsion and Aerodynamics, and after it was abandoned the responsibility for upper atmosphere research passed to Flight Projects Group. It was Flight Projects which conducted the first Skylark trials in 1957. But in addition to this, throughout 1957 and most of 1958 Britain was preparing to launch the ballistic missile Black Knight at Woomera, and WRE was hard at work developing instrumentation for the purpose of recording trajectories and rocket behaviour at previously unattained heights. There was a demand for small test vehicles and sighter rockets to reach high altitudes, and Flight Projects responded quickly by designing a two stage rocket called Long Tom, assembled from surplus British solid motors already to hand. Long Tom was first launched in 1957 with fair success, and brought with it the realisation that here was the means to conduct a large independent research program. Over the following years a succession of at least ten different vehicles was produced. Developed specifically for their research applications, they steadily improved in reliability and performance. The use of British motors was supplemented in many cases by new designs originating at WRE. By 1970 BDRSS was reporting that WRE now possessed the means of obtaining continuous data on atmospheric conditions from ground level to over 180 kilometres altitude, and moreover was co-operating in a joint project to investigate flight aerodynamics at hypersonic speed.

Friendly rivalry between the partners played no small part in the upper atmosphere research conducted at Woomera. Indeed, had it not been for the impetus of the International Geophysical Year and the presence of Skylark the Australian program might well never have started at all. Nonetheless, the two efforts did mesh well enough, and the work continued for fifteen years to a total of almost 400 firings until it was eliminated with the economies applied after 1975.



Over 200 British Skylark sounding rockets were fired during the joint project's longest running trials program (1957-78). This early single stage version used a long burning solid Raven motor, which gave the scientific instruments carried a gentle ride into the upper atmosphere.

THE DEVELOPMENT OF SKYLARK

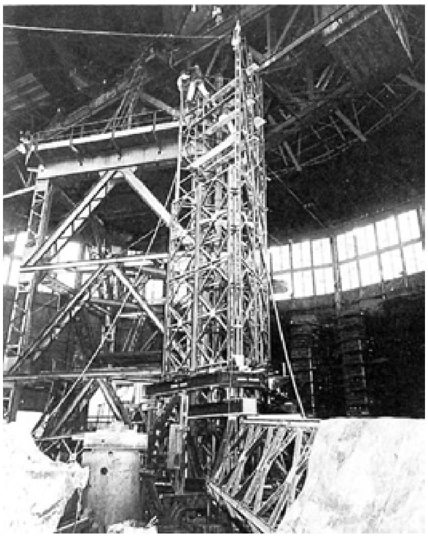
By the mid-1950s the Guided Weapons Department at RAE had plenty of experience with solid propellant rocket designs. Frank Hazell of the Aerodynamics Section had led the design work on the earlier CTV5 series I, and he now turned to the new task of a rocket with a higher performance. A solid motor had already been considered for Black Knight, but was rejected for various reasons discussed in the next chapter. Skylark was a different matter; it was to be unguided in flight and some of the many planned launches were going to require a very precise lift-off time. In the circumstances a solid propellant motor was the ideal choice.

The first design for Skylark was a single stage rocket propelled by a large solid motor called Raven. The motor formed the main body, and was surmounted by a cylindrical compartment of the same diameter topped by a long nose cone. For flight stability, three large fins were mounted at the rear end. The thickest diameter of the rocket was 44 centimetres and it stood about 7.5 metres high, depending on the length of the instrumentation compartment which could be varied according to the payload space required.

The Raven was the main propulsion unit on all Skylarks, although more than ten variants of the motor eventually appeared with different characteristics. The salient feature of all Ravens was their low thrust, which continued for a relatively long burning time of about 35 seconds. The intention was to avoid damaging the delicate instruments by keeping the acceleration down to 12 g or less. The low acceleration also improved the performance, because the rocket attained full speed only after passing rather slowly through the denser lower levels of the atmosphere.

The first Skylark, launched on 13 February 1957, had the single stage configuration, as did the next twenty-three. In April 1960 a two stage version was flown. The original Skylark rocket was now the upper stage and used the Raven as a sustainer motor. To the rear was attached a quick burning Cuckoo boost motor. This added about 2 metres to the length of the rocket. Henceforward most Skylarks had two stages; much later, in February 1968, a more powerful boost called Goldfinch was employed for the first time, together with an advanced Raven type 6A. The combination was very successful.

The performance of the different Skylarks varied a good deal, depending on such factors as the payload mass and the launcher's angle of elevation. Typically however, assuming in each case a 200 kilogram payload, the single stage vehicle had a peak altitude of 110 kilometres, while the boosted vehicles with Cuckoo or Goldfinch could reach 205 kilometres and 270 kilometres respectively.[2]



Right: Assembling the Skylark launcher in the Round House at Woolwich Arsenal, to check that the panels fit before shipping them to Australia (MOD).

Far *right*: Raising a Raven motor into launch position, using a transport trolley which then formed part of the launcher tower.

Skylark was unguided in flight. The trajectory was set primarily by the angle and direction at which it was launched but it was also influenced by the wind, and this had to be taken into account in fixing the launch direction and angle. The low acceleration had its disadvantages. Until the rocket had reached a sufficiently high speed, its stabilising fins gave little aerodynamic assistance and the vehicle could topple. Even after stability was attained the slow-moving Skylark was very susceptible to cross-winds.

The Skylark launcher was designed to overcome most of these problems. It was an odd-looking device consisting of a tall central tower 30 metres high supported in its middle by gimbals attached to a strong tripod base. The gimbals allowed the tower to be tilted around its vertical and aimed in the desired direction like a huge gun barrel. The Skylark was propelled up the tower along three guide rails, emerging at the top with sufficient speed to maintain its stability. The launcher, weighing some 35 tonnes, was built cheaply from Bailey bridge panels by the Woolwich Arsenal in England and shipped to Woomera in segments.

Before each Skylark took off, balloon-borne instruments took wind measurements to a height of 18 kilometres or more so that corrective adjustments could be made to the tower aiming position. These adjustments helped reduce the flight dispersion, or undesirable errors in trajectory and the final point of impact. Dispersion effects caused problems for Range safety and for payload recovery, and had to be minimised. The planned impact was typically between 80 and 160 kilometres down- range, but WRE recorded that all the flights up to 1969 generally missed the point by 20-30 kilometres and sometimes much more.[3]

Most disturbing was the second firing in May 1957, when the Skylark roared off far to the right of its intended path. Taken by surprise, few of the tracking instruments kept up with it and its impact point was not calculated for some time; but it had obviously transgressed the northern Range boundary. It was one of the very few occasions when this unforgivable sin was committed at Woomera; but fortunately it did no harm in such a sparsely populated region. What had happened was that, when working out the procedures for setting the launcher to compensate for winds, one rather elementary geometrical calculation had been forgotten. Peter Twiss, in charge of the small WRE team of aerodynamicists who were calculating wind corrections, later put the oversight down to the launcher and its instruments having been designed in Britain and the procedures for correcting for wind in Australia. There was no chance of the problem recurring, and, as Twiss said later, 'very wisely it was decided not to go and look for [the Skylark] because that would have drawn attention to it'.[4]

While wind was the chief cause of dispersion it was not the only one. There were as many as twelve other contributory factors, the principal ones being various misalignments in the vehicle and motor thrust which could be reduced to a degree by accurate construction. To improve matters, a way of reducing the effect of vehicle misalignments was introduced in later Skylarks. They were spun around their long axes at a rate of about one revolution in two seconds, by firing small rocket thrusters (Imps) fitted around the circumference of the boost motor, and also by the aerodynamic method of slightly canting the fins.

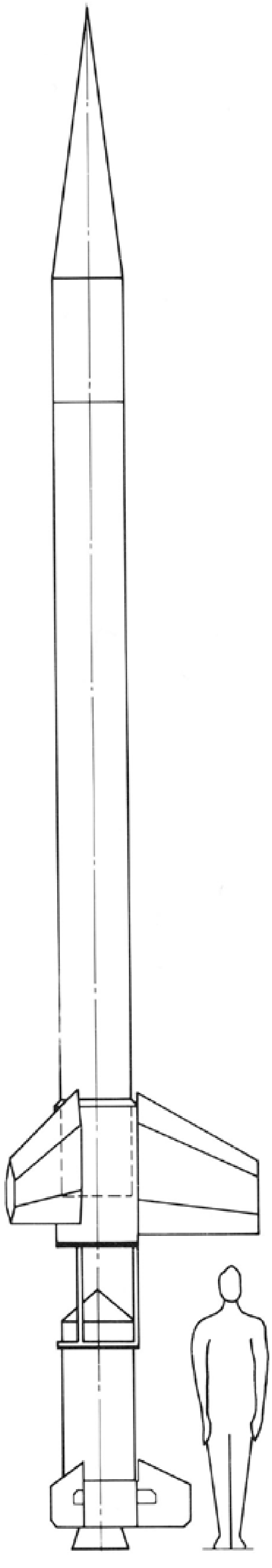
The later Skylarks had an attitude control. Some experiments, especially the astronomical observations, required the instrument compartment to be detached from the rocket body late in flight, to be de-spun if necessary, and then held in a fixed attitude relative to the sun or stars. Elliott Bros and later Marconi worked with RAE to develop a series of attitude control systems which were remarkably successful. They depended on sensors which recognised the chosen celestial point and kept it fixed in their field of view by controlling the position of the head with small nitrogen jets. By 1965 the sun-pointing attitude control system was in frequent use, followed by a star-pointer in 1970. The pointing accuracy was within 30 seconds of arc.[5] The data obtained by Skylark was usually telemetered to the ground, but in some cases—where photographs were taken, for example—the head returned gently to earth under a parachute.

From the start there was no shortage of work for Skylark: BDRSS reported in 1962 that there was a long waiting list for payload space. Over twenty universities and organisations in Britain and Australia wanted to fly their experiments and instruments, and it fell to the British Science Research Council and the Space Research Management Unit to sort out and allocate the experiments to particular vehicles; several went in each Skylark when their functions were compatible. There were international users too. NASA paid for four Skylark firings in 1961 to investigate ultra-violet radiation from space, and European universities were represented in six ESRO-sponsored launchings in 1970-72. The technical co-ordination in Britain, and the development of Skylark, was handled by RAE, where most of the rockets were assembled and tested before shipment to Woomera. Some Skylarks, about one in five, were built by WRE.

The Skylark trials at Woomera were handled in an unusual fashion, administratively speaking. Most of the other British projects were prepared and launched by a Range user provided by the R&D authority and staffed by men from the British establishments, their contractors, or an appropriate services detachment. Skylark was different. For much of its Woomera career the Range user functions were carried out by a WRE team from the Weapons Research and Development Wing, just as if it had been an Australian-sponsored project. Normally the sponsoring UK university or other establishment sent out a small team to look after their experiment, but their enthusiastic activities were co-ordinated by an officer in scientific charge appointed for that trial from the WRE team. The Range authority aspects of trials planning and conduct were handled in the normal way by Trials Division of WRE.[6]

Systems Assessment Division of WRE, which had earlier handled Range user aspects of the RTV1 and CTV5 series I firings, continued this for the first two firings of Skylark, in February and May 1957. They were performance-proving vehicles carrying no experiments, and this was perhaps fortunate as the first reached only a low altitude and the second landed far from its planned impact point, as we have seen. Once these teething troubles were corrected Skylark went on to become a very successful project. Responsibility for the trials passed to Research Vehicles Group in Aerodynamics Division (AD), who launched the third Skylark in July. Belfast University had the honour of providing the first experiment, which unfortunately failed although the rocket performed satisfactorily. Research Vehicles Group expanded subsequently and by 1963 was fielding four separate teams so several Skylarks could be prepared at once. From this time on the only run of bad luck with Skylark was between November 1963 and February 1964, when five consecutive flights failed owing to various structural failures. The problems were remedied and Skylark soon regained its reputation for reliability, as was amply demonstrated in April 1965 when no fewer than seven Skylarks were successively launched in one night in order to measure changing atmospheric conditions. The 100th Skylark was launched in September 1964 and the 150th in April 1967.

Aerodynamics Division gave up Skylark in January 1969 when the British Aircraft Corporation in Australia was given a contract for future work, the British parent company having already taken over the task of assembling the rockets in Britain. The transfer brought some changes in trials arrangements. The preparation work was now done entirely at Woomera (rather than partly at Salisbury as hitherto) and the launches were concentrated into a series of 'campaigns' instead of taking place evenly throughout the year. The system worked well and BAC continued to operate the trials program after a further change in April 1974. After this date RAE no longer supplied Skylarks and the task was taken over by the Appleton Laboratory of the Science Research Council. The SRC therefore became the Range user at Woomera, retaining control of the BAC contract services for preparation and launchings.

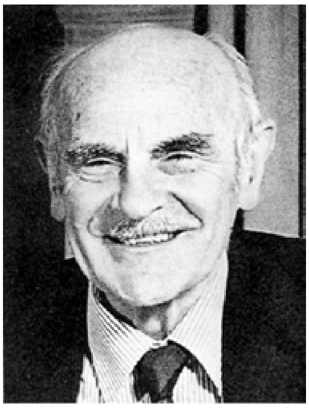


The later two stage version of Skylark. A quick-burning Cockatoo boost was attached to the Raven, now used as a second stage.

Research Vehicles Group and others gather to celebrate the Skylark century.

Skylark ceased to fly under the joint project in 1979. The facilities at Woomera were diminishing by then and the rocket itself was getting more expensive: what had started out as a cheap means of taking an instrument package into the ionosphere had become a sophisticated research tool in its own right. For astrophysical investigations at least, satellites now offered the same facilities at lower cost, and they also offered much lengthier periods of observation.

SKYLARK EXPERIMENTS



Professor Sir Harrie Massey, who led the UCL team responsible for most of the early Skylark experiments. He was also chairman of the Gassiot sub-committee dealing with sounding rockets. (Godfrey Argent)

The scientific experiments carried by Skylark during its long career were so numerous, various and technical that it is impossible to do more than survey them and note some of the more outstanding events. Most experimenters had long-running research to pursue and they returned with new flight equipment year after year. University College London (UCL) was perhaps the most persistent; from the start of the project its contributions to the payload appeared unfailingly every year.

UCL sponsored one of the earliest experiments, which was to measure the temperature of the atmosphere at heights of up to 100 kilometres. This was done by indirect means, by ejecting a series of grenades from the Skylark at various heights. The flashes of the grenades, arriving practically instantaneously at the speed of light, were timed against the delayed arrival of the much slower shock waves travelling through the air and recorded by an array of microphones. The temperature of the air at different levels could be deduced from the speed at which the sound waves passed through it. These measurements continued for several years of trials in conjunction with other experiments. The same vehicles also measured the speed and direction of high level winds, by ejecting various materials from the rocket and observing their drift. The Imperial College method was to release 'window', or 'chaff: a cloud of thin metallised strips which floated in the wind and could be tracked by ground radar. (The material was used in the war to confound enemy radars.) The Queen's University Belfast chose to eject sodium vapour instead, which was effective at greater heights than window and produced a drifting luminous trail in the sky which was strikingly visible from a great distance and could be photographed to show the motion of the tenuous air.[7] Various other substances were used in this way, sometimes to determine the composition of the ionosphere by chemical reaction. In May 1968 Skylarks emitting trimethyl aluminium (TMA) were launched at dawn and evening twilight to compare conditions at those times of day, and the spectacular effects were visible from Adelaide.

Many elements of the high atmosphere were measured directly by rocket- borne instruments and telemetered to the ground. One was the level of ozone, a subject always of interest to the British Meteorological Office, which provided equipment to measure ozone concentrations on many occasions. One such measurement in April 1964 was timed and launched to coincide with the passage overhead of the UK2 satellite, which was taking similar measurements further out. The structure and composition of the ionosphere was investigated by detectors giving quantitative measurements including electron and ion density and magnetic field strength. Radio propagation into the ionosphere became a combined trial by Bangor University College, RAE and WRE, requiring much ground equipment and lasting for ten years up to completion in 1969.[8]

The measurement of electromagnetic radiation from space, especially of those frequencies which are blocked by the atmosphere, was a lively research topic throughout the Skylark years. UCL and Leicester University studied X-ray emission from the sun from 1959 onwards and in May 1961, just before the NASA UV trials, UCL first measured the solar ultra-violet flux in the southern hemisphere. But it was the introduction of Skylark attitude control in 1965 which brought new opportunities to the experimenters. It now became possible to survey the celestial hemisphere to locate sources of extra-terrestrial radiation; and having done so, to fix upon and study the source in depth. Leicester University took a leading part in these investigations, while in early 1967 the Universities of Adelaide and Tasmania discovered a powerful new X-ray source near the Southern Cross. The accuracy of the sun-pointing attitude control system also allowed a whole range of solar physics investigations to proceed. From 1966, the Culham Laboratory and several others were recording the sun spectrum over a series of wavelengths from X-rays to extreme ultra-violet. By 1971 selected regions of the solar corona were being examined by high resolution spectroscopy, and the Mullard Space Science Laboratory (MSSL) was studying line spectra from small areas of the solar disc in order to make temperature estimates.

Probably the major achievement of Skylark—Leicester University, the BAC launching team and the Range were all involved in this—came in September 1971, at the behest of radio astronomers who wished to fix accurately the position of the X-ray source, GX3+1, deep in space. This was to be done by using an X-ray detector to record the exact instant when the edge of the moon passed in front of the source, temporarily cutting off its radiation. This rare event would not recur for twenty years, so it required a reliable and very precise moment of launch. The instrument lock-on was obtained first by detecting the X-ray source, Scorpius, and then by supplying data to the attitude control unit to achieve the correct orientation. The result was a complete success. Coupled with a second measurement of the source a month later using an MSSL detector, it fixed the position of GX3+1 to within two seconds of arc.[9]

Although Skylark's glamorous astronomical work rather obscured its more mundane atmospheric investigations, these continued unabated. In 1971 the ionospheric structure was still being explored by grenades and chemical injection, and in 1972 the daytime winds of the upper atmosphere were recorded using a sodium-lithium trail, with ground detectors (developed by WRE) which could observe it in daylight.

Towards the end of its life Skylark was turned away from space and the earth's atmosphere to the earth's surface, the object being to observe and photograph ground conditions and resources. This technique of remote sensing was already in use from aircraft and satellites, and it had proven valuable for agricultural and mineral exploration purposes as well as for oceanography and geology. It was thought that using rockets like Skylark would fill a gap between aircraft and satellites. It would give a wider field of view than aircraft-mounted cameras, and would be better than a satellite for choosing observation times and in recovering instruments and photographs intact.

Much preparation was necessary, as several organisations had an interest in the results. Reading University, with its strong agricultural speciality, was one sponsor, and in Australia the Mineral Physics and Soils Divisions of CSIRO, the Departments of Mines, Agriculture and Lands, and Adelaide University all participated. The object was to compare Skylark's observations with those obtained for the same regions by aircraft photography and by the NASA satellite ERTS-A, and also by inspecting the terrain and vegetation on the ground. The latter inspection was carried out at five selected areas of South Australia, from Wilmington to Ceduna. RAE built the Skylark and gave it two automatic cameras to photograph the ground in visible and infra-red light. The rocket head was attitude-stabilised in two planes by horizon sensors, but was programmed to turn through a series of 60 degree steps in the third plane as the photographs were taken. The launch on 27 March 1972 met all the objectives. From a height of 190-280 kilometres the Skylark cameras took 120 photographs of areas of the surface with a radius of up to 370 kilometres, and all of them were recovered safely. They were interesting to the general public and were shown at various exhibitions in Australia and Europe.[10]

ALL-AUSTRALIAN SOUNDING ROCKETS

It has already been described how WRE's first sounding rocket, Long Tom, was originally a cheap vehicle built to test the Range instrumentation for the forthcoming Black Knight and other high altitude trials. Two groups of Systems Assessment Division co-operated in the work: Flight Projects under Des Barnsley handled the mechanical design and Project Studies led by Peter Twiss dealt with aerodynamics and performance estimates. It was put together entirely at WRE using surplus solid Mayfly motors—a cluster of three to form the boost and a fourth one as the second stage. With its overall length of 8.2 metres and a second stage diameter of only 23 centimetres, it had the shape of a long needle, with three fins like Skylark's at the rear of the boost assembly to give aerodynamic stability. At that stage Flight Projects's main ambition was apparently to produce a vehicle that would fly higher than Skylark, although this was not the official reason for Long Tom. Twiss recalls the almost conspiratorial atmosphere:

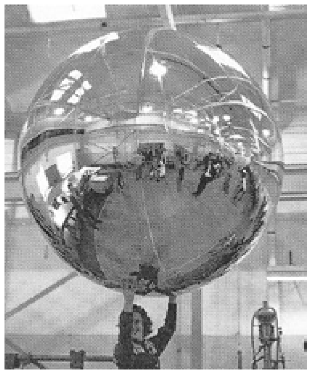
> I can distinctly remember Boswell being taken in there with all us young guys hovering around. Of course by then it was apparent that we were really competing for altitude honours with Skylark. Boswell looked at it, walking round and humming and hawing away as old Boswell used to do. And he said something like, 'Yes, yes, very interesting . . . but I know nothing about it.' Which was a typical Boswellian remark. We actually had tarpaulins on it and they were thrown back over.[11]

Long Tom, the first successful Australian sounding rocket, on its own launcher.

The first Long Tom was fired from the Skylark launcher in October 1957 and it worked well, reaching a greater height than had Skylark for its first disappointing firing, much to the elation of the Flight Projects team. The third Long Tom suffered a partial boost failure, which damaged the launcher slightly and brought a request from RAE to refrain from using it again. This left WRE with no means of launching it, but in the spirit of the times the Establishment quickly put together its own launching rail. It was trainable in direction and elevation but only 3 metres long. Unlike Skylark, Long Tom accelerated so fast that it did not need the stability imparted by a long launching rail.

Now that Long Tom had proved itself, it could be put to work. Over the next ten months five more were fired to test the MTS optical trackers and impact predictor that formed part of the Black Knight safety system, and also to test a shock wave detector which, it was hoped, would help to locate the impact points of Black Knights. Up to then nobody saw Long Tom as an upper atmosphere research vehicle. But late in 1958 Bryan Rofe was transferred from Missile Projects Group to head a new meteorological research section of Flight Projects. Rofe had had a varied career at WRE, but his training was in meteorology and he was keenly interested in using the International Geophysical Year to gather new data, particularly below 80 kilometres. In Long Tom he now had an Australian vehicle to hand. While Long Tom continued as an instrumentation test vehicle, Rofe began to use it for upper atmosphere research. It had already ejected window at high altitudes to measure winds, but this had been in connection with Black Knight. The first experiment conducted for the International Geophysical Year was a micrometeorite detector supplied by the Australian National University and fired aloft in May 1959. So began the expansion from the original purpose. Long Tom was not the only Australian high flyer at this time. A second rocket, Aeolus, had been designed and built, also from surplus components. It had the same second stage as Long Tom but a shorter, less powerful boost formed from a cluster of seven LAPSTAR motors.[12] Its performance was therefore lower, with a peak altitude only half of Long Tom's 120 kilometres, and although it was good enough for small payloads it fell out of use after 1961.

Long Tom continued intermittently for several more years, but it was not a very good research vehicle and its successors were already being designed.[13] When Bryan Rofe succeeded Twiss as team leader early in 1960 two new sounding rockets took shape under his energetic direction. They were called High Altitude Density (HAD) and High Altitude Temperature (HAT); unglamorous names which did however reflect their functions. Both continued to use redundant British solid motors.

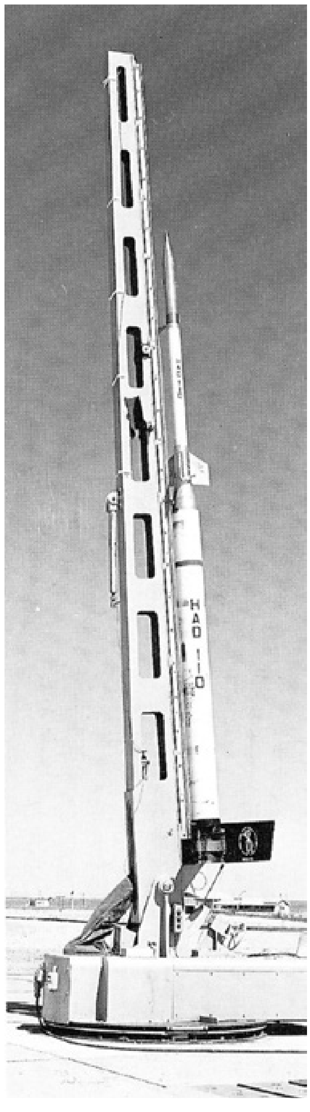


The balloon used for the falling sphere experiment.

HAD used a Gosling boost motor with LAPSTAR as its second stage. It achieved a peak altitude of 120 kilometres and was used for a number of years for a variety of purposes, principally the 'falling sphere' experiments. The sphere was a 2 metre diameter balloon made of aluminised polyester film, which was ejected from the rocket when the latter was close to apogee and was inflated at extremely low pressure as it emerged. The balloon descended slowly through the atmosphere, its movement continuously tracked by ground radar, and it took about twenty-five minutes to descend to the 30 kilometre level, by which point it had collapsed. The first successful release took place at dusk on 29 March 1962, when the sphere was clearly visible as a bright star. Sphere launches continued at regular intervals and in 1966 they had become a routine monthly measurement of air density, temperature and wind, providing what is still considered one of the best consistent sets of seasonal atmospheric data.

In 1964 a series of falling sphere HADs were launched simultaneously at Woomera and Carnarvon in Western Australia to investigate the variations in atmospheric density and winds over part of Australia. At Carnarvon the US Space Tracking Centre provided radar tracking. Large rockets had never been fired before away from Woomera or other ranges. The first launch site was selected just out of town, on what appeared to be level and solid ground. A combination of high tides and heavy rain turned it into a swamp. Over the first four firings the launcher slowly sank into a hole made by the rockets' efflux, and the firing team left behind a trail of hopelessly bogged trucks and graders belonging to the Town Council. A good portion of the town's population watched these activities with interest, crowded into the racecourse grandstand which was conveniently adjacent, and listening to a running commentary. A return visit by the WRE team was perhaps less popular:

> One of the rockets deviated from the intended trajectory and went up almost vertically. For the next two minutes a rather worried radar operator gave repeated reports that the elevation was still 90 degrees. Then a loud series of sonic bangs heralded the return of various parts to earth. The head landed 10 metres from a man working in a road gang, and it was alleged later that he was speechless for 24 hours and then did not stop talking for a week. The Mayor of Carnarvon suggested very politely that the next time it would be better if we moved farther from the town.[14]

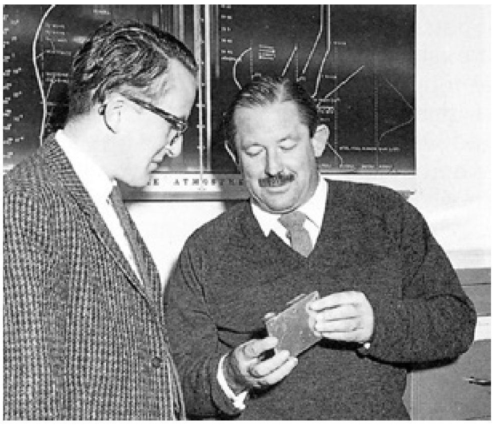


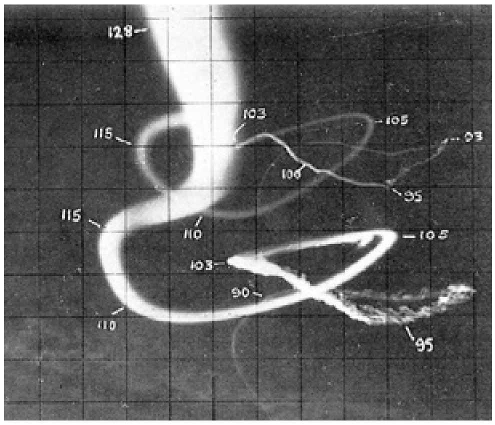
HAD on its launcher.

The final campaign was to launch ten HAD rockets over 24 hours in an ambitious program for examining the diurnal effects of atmospheric changes. The new site was 60 kilometres north of Carnarvon on a rocky sea shore, but despite the arduous conditions everything went smoothly and the trials produced a great deal of significant and unique data.

From 1962 John Carver, Professor of Physics at the University of Adelaide, used HAD and Cockatoo to investigate the chemical composition of the upper atmosphere, particularly the profiles of molecular oxygen and ozone. The payloads were designed jointly by WRE and the University, in a collaboration which gave graduate students an unrivalled opportunity for research in this difficult field. Indeed, the University had a monopoly in it, which meant that a good part of the sum total of knowledge about the physics of the upper atmosphere in the southern hemisphere was coming from Adelaide in these years.

The HAT rocket also used LAPSTAR as its second stage, but its first stage boost consisting of two Demon motors was less powerful than HAD, resulting in a lower peak altitude of 75 kilometres. It was generally used to deploy a parachute- borne dropsonde, which descended slowly through the atmosphere carrying its payload of sensing equipment to measure air pressure and temperature directly, telemetering the data to the ground. Later experiments measured the ozone and molecular oxygen concentration at high altitude. An interesting feature of the dropsonde trials was the airborne recovery method. An Alouette helicopter flew over the dropsonde as it fell slowly, and caught it up with a hook suspended on a cable about 10 metres below the helicopter. Dropsondes were recovered in this fashion for some years, until, during a practice session at Woomera, the steel cable wrapped around the drive shaft to the tail rotor and sheared it. The helicopter landed safely, but the technique was abandoned afterwards as unsafe.[15]

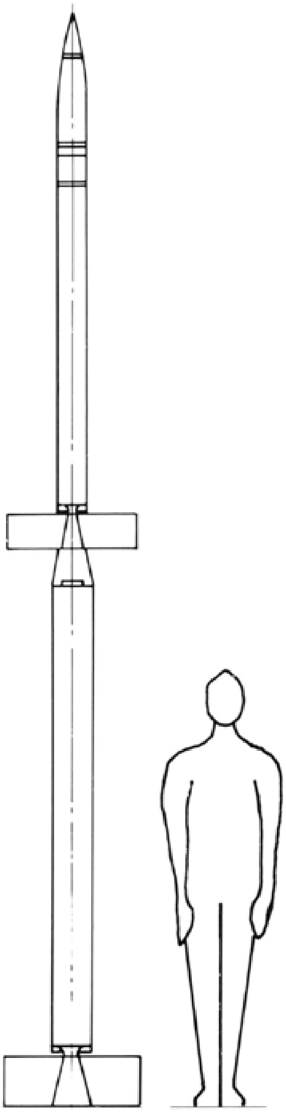




Right: Bryan Rofe (right), who pioneered the WRE sounding program, with his successor Phil Pearson.

Far right: A glowing lithium trail from a Cockatoo rocket 10 minutes after firing, showing the drift due to winds. The figures are heights in kilometres on both ascent and descent.

In 1967 practically no upper atmosphere research was done at WRE as the whole of Flight Projects Group under Bryan Rofe was working flat out on the WRESAT satellite. When it resumed its normal tasks in 1968, Flight Projects started developing a new generation of sounding rockets to designs laid down by P. H. O. (Phil) Pearson. HAD quickly disappeared from view, but HAT was frequently in use for a further two years and occasionally at later dates as well, although by that time better alternatives were available. An interesting HAT launching took place in late 1968, when it was successfully fired to coincide with the passage overhead of the satellite Explorer 37. HAT gathered data on ozone and molecular oxygen distribution over a vertical profile, while the satellite took similar observations on a near-horizontal path above. WRE's new sounding rockets[16] were (with one exception) named after Australian birds. The first to appear on the launcher was Kookaburra early in 1968. By this time the motors also were being replaced by Australian versions, named after the constellations of the southern hemisphere. Kookaburra's first and second stage motors were called Lupus and Musca respectively. It was a small rocket; its overall length of 3.4 metres was less than half Long Tom's, but with its second stage diameter of only 9 centimetres it appeared equally needle-like. It did the same type of work as HAT, releasing an instrumented dropsonde from high altitude, and it achieved the same apogee of 75 kilometres. Kookaburra remained in use until 1975, averaging eleven firings a year. Its international highlight was the Indian Ocean experiment in March 1970, when a group of firings was carried out simultaneously with Britain from Gan and India from Tumba, as a comparative assessment of atmospheric temperature and ozone levels.[17]



This small Kookaburra was the first of a new generation of WRE sounding rockets using specially developed motors. It replaced an earlier HAT ('High Altitude Temperature') rocket.

Cockatoo, a large rocket 6.3 metres in length, made its debut in early 1970 replacing the obsolete HAD. It employed a British Gosling 1 motor as its boost and with the Australian Lupus as the second stage reached 130 kilometres. Over sixty Cockatoos were launched during the next five years, about two-thirds of them being falling sphere trials as a resumption of the earlier HAD program. Cockatoo, however, had greater capabilities and most of its other trials were lithium-trail experiments to measure winds and turbulence at about 80 kilometres altitude. It also made measurements of ozone concentration, ultra-violet radiation and other ionospheric conditions.

The third new rocket to come into use at this period was Aero High, the independent product of WRE's Aerodynamics Division. It was the largest of the three newcomers, 6.8 metres in length, using a Gosling 4 motor as its first stage and a Vela motor as the second, and could achieve an altitude of 200 kilometres. Its main purpose was to investigate chemiluminescent reactions on behalf of Propulsion Division by releasing grenades and several different chemicals at high altitude.

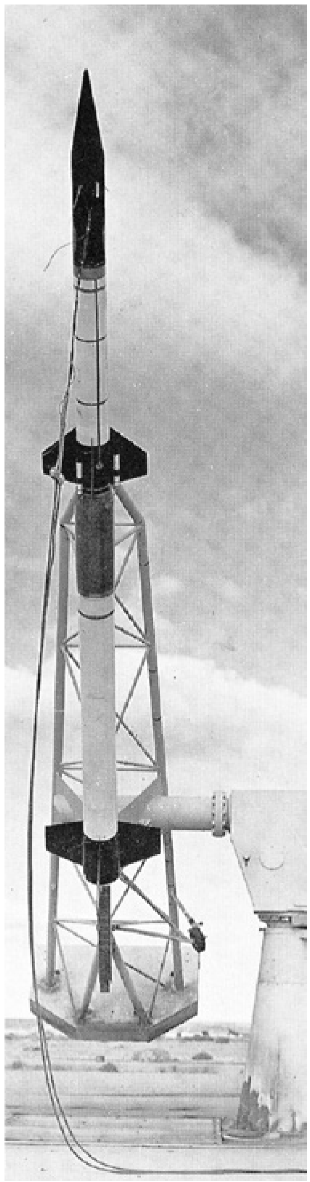
Apart from two early flight tests of Aero High as early as mid-1964 which were not fully successful, the main program consisted of twelve launches between 1968 and 1972. They all carried grenades which were ejected to form glow clouds, while the chemicals dispensed were lithium vapour, nitrogen tetroxide and TMA. Aero High performed quite well, although the nitrogen tetroxide failed to produce the expected luminescent trail. It was also fired in company with Kookaburra and Cockatoo in 1970-71. Up to six rockets were fired at intervals over a period of about ten hours, mostly in darkness, to obtain a coherent series of atmospheric readings at high altitudes ranging from 25 to 200 kilometres. The results were unfortunately degraded by some rocket failures in each sequence of firings.

A change in the organisation of upper atmosphere research at WRE was introduced in 1969. For many years the work in this area had been divided between two separate divisions of the Establishment: Systems Assessment and Aerodynamics. The work was now concentrated in a new group—Upper Atmosphere Research (UAR)—which formed part of a renamed Aerospace Division.

In 1970, WRE undertook a short intensive program of sounding rocket launchings on behalf of the Australian Bureau of Meteorology. The vehicle, a simple American rocket, was called HASP (High Altitude Sounding Projectile). HASP released window at about 60 kilometres to obtain radar records of wind speed and direction at greater heights than meteorological balloons could reach. Almost 100 HASPs were fired over the two years of the program.

While the newly formed UAR Group was handling its program of flight trials it also developed two more sounding rockets, although neither lasted long before all activity in this sphere came to an end. The first was Lorikeet, a combination of a Dorado boost motor and Lupus second stage, intended as a further improved version of the long-standing HAT for dropsonde purposes. Four Lorikeets were fired from late 1973 onwards. Corella was a more powerful rocket intended to supersede Aero High. Its motors were Gosling (or alternatively Indus) with a Dorado second stage. Only two Corellas were launched before research finished. Both Lorikeet and Corella were developed under the leadership of Phil Pearson, who had taken over UAR Group after Bryan Rofe had left to lead the Antarctic Research Division of the Department of Supply in 1970.

Rofe was missed by the UAR workers—that the research program ever got off the ground was due largely to him—and by the WRE community generally. He was a flamboyant man with a sharp wit. On one memorable occasion he was in Leningrad, attending a COSPAR space conference. The Russian hospitality included bus tours around the city, scene of some of the cruelest fighting of World War II. The guides missed no opportunity to extol the bravery of the Red Army against the German invader at fulsome, and eventually tiresome, length. One day a guide was haranguing the party as usual when he noticed Rofe chatting away and ignoring the flow of rhetoric. The guide was unwise enough to remark cuttingly: 'I see the delegate from Australia is not interested in the way we fought and drove the Fascist beast from the Motherland.' This was altogether too much for Rofe, who had himself served bravely with the RAAF in Timor, behind Japanese lines. 'Listen, sport', he shot back. 'Don't you tell me about fighting Fascism. I was fighting Fascism while your Joe Stalin was kissing Hitler on both cheeks!' The whole bus erupted at this riposte. For Twiss, who tells this anecdote, the secret of Rofe's achievements was an ebullient personality, an ability to inspire people with a vision, and a carefully nurtured circle of university and international scientific friendships.



Largest of the new generation WRE sounding rockets was this 6.8 m Aero High.

All upper atmosphere research at WRE ended in 1975, a casualty of the thorough review of all work which preceded the winding-up of the joint project. Like many another activity at Salisbury it was terminated just when the growing pains were over and it was starting to yield long-term results; but the fact remains that it was (within the context of what WRE was supposed to be doing) an indulgence—pure scientific research without obvious defence implications—and apparently its continuance could not be justified in a tougher economic climate.

HYPERSONIC RESEARCH AT WOOMERA

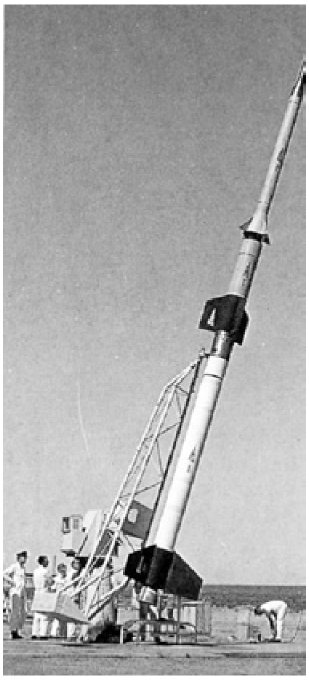
Hypersonic aerodynamics, which is the study of airborne flight at more than five times the speed of sound, was a lively research topic throughout the 1950s and 1960s. There was the British interest in ballistic missiles; but also both the military and civil authorities were examining the possibility of hypersonic aircraft. A good deal could be done with theoretical studies and with wind tunnels; but both had their limitations, especially ones stemming from inadequate computing power. What was needed in addition was a program of rocket trials, to test and to supplement data obtained by other means. One particular area of uncertainty which needed to be probed by rocket trials was the heating of the airframe by friction at hypersonic speeds.[18]

In 1957 aerodynamics groups at both WRE and RAE were studying designs for a suitable hypersonic research vehicle (HRV). This mutual interest was formalised the following year with an agreement, approved by the joint project, to work together on a multi-stage rocket capable of reaching a speed of 2500 metres per second, corresponding to nine times the speed of sound at an altitude of 20-30 kilometres. Initially the work of each partner was led by Lance Brooks of WRE and James Hamilton of RAE, but many others on both sides contributed over the years. The HRV rocket retained the name Jabiru right through the twelve years of the program, even though the configuration of the vehicle was progressively developed, both in the number of stages and in the type of motors used. The name Jabiru (a type of stork) followed WRE's policy of choosing native bird names for its later research rockets. At first RAE called the three stage version Jaguar, until confusion with the Jaguar aircraft caused them to adopt the Australian name.

Launch of a Jabiru Mk 1 hypersonic research vehicle.

The practical development of Jabiru began in July 1959 with the proving tests of a two stage prototype. Six vehicles were fired at Woomera with variable results, as they tended to destroy themselves in flight, bending to a banana shape which imposed intolerable side forces. But by December 1960 the Jabiru Mk 1 was ready for testing. It had three stages, each using a different British solid motor: they were called Rook, Goldfinch and Lobster and ten Jabirus of this type were launched over the next four years. In October 1964 the Mk 2 design was introduced, employing a more powerful Goldfinch motor as the second stage, while Gosling replaced Lobster as the third stage. So equipped, Jabiru Mk 2 could carry a 90 kilogram payload, and flight experiments using twelve rockets of this type continued until December 1971. It was a most reliable and effective test vehicle.

Jabiru was unguided and, like the other UAR rockets, it suffered from dispersion; like Skylark it was spun in flight by small lateral rockets to reduce this. Its high acceleration made a long launcher unnecessary. In fact its first launcher was of 'zero length', although it could still be aimed to offset the effects of wind. In 1969 a new launcher with a track of 4.5 metres was introduced to take heavier vehicles.



Jabiru Mk 2, then known as Aeromach, on the zero-length launcher.

The experiments carried by Jabiru consisted mainly of specially instrumented models which were mounted at the head of the rocket and projected into free flight when the propulsion ceased. The later experiments were recovered by parachute. The models were sometimes specially shaped nose cones of various types to measure the effects of aerodynamic heating, while in other experiments they were sophisticated aircraft-type wing forms. One model, Oberon, was almost a scale model of a full aircraft shape. Oberon was launched on three occasions in 1967-69 to a speed of Mach 4.5, when the aerodynamic heating raised it to a temperature of more than 600°C.

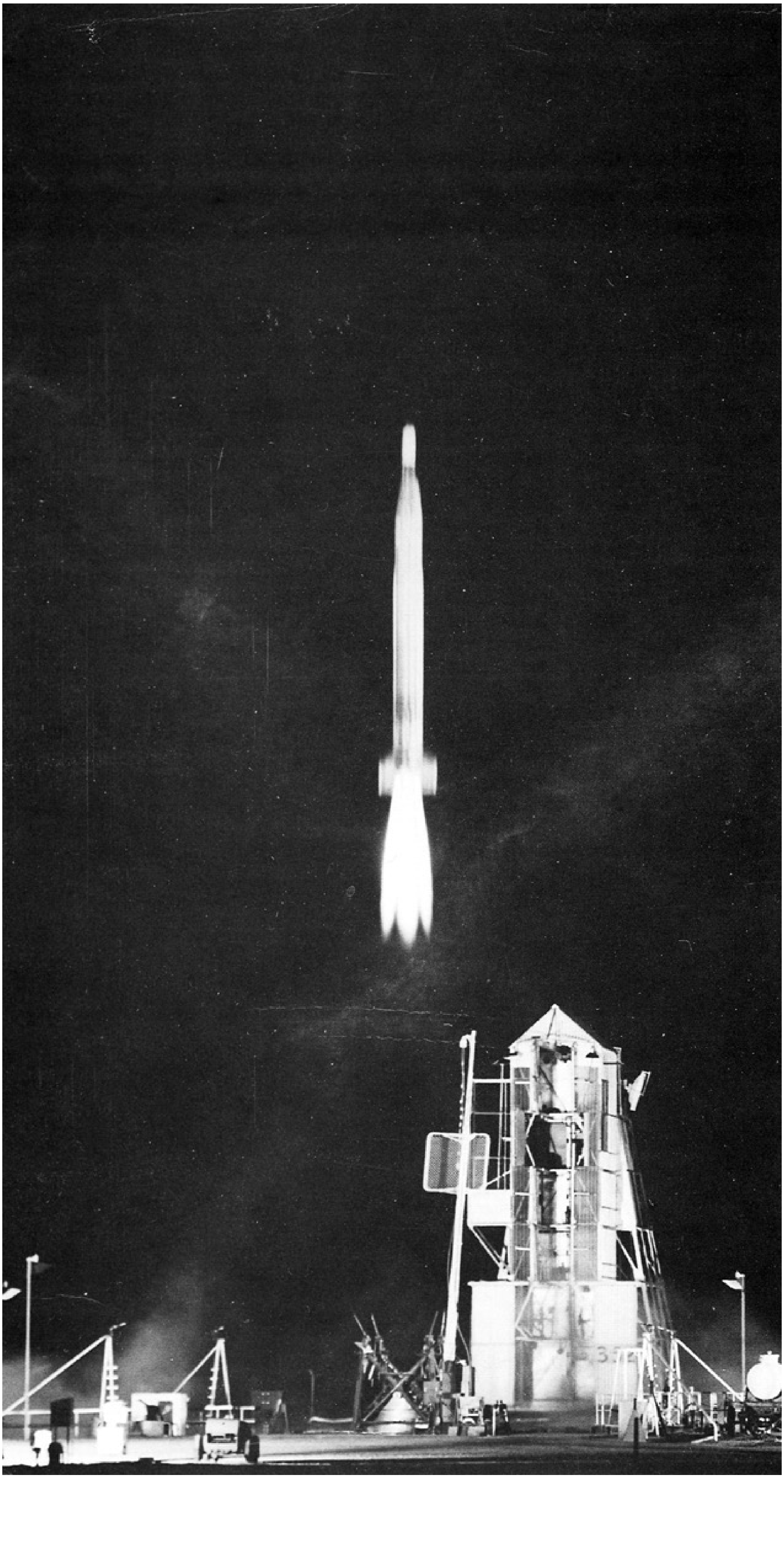
The HRV research program finished in April 1970 but Jabiru continued for several years longer in another project which investigated more severe heating effects at lower altitudes of up to 15 kilometres. Another version, Jabiru Mk 3 with two propulsion stages, was produced and flew five times before the task was complete in November 1974. By then, much of the early interest in hypersonic flight had waned.

Notes and Sources

1. The Gassiot Committee administers a bequest from one Gassiot, a FRS and rich wine merchant, made in the 19th century. Its terms were to provide for the study of physical phenomena relating to meteorology. The chairman of the Rocket Subcommittee at the time of the IGY was Professor H. S. W. Massey. Events leading up to the start of the Skylark project have been described in detail by Massey, who places his first contact with the Ministry of Supply as an informal approach by an official in May 1953. Subsequent collaboration with RAE was confirmed after a meeting at Farnborough in February 1954. See H. Massey & M. O. Robins, *History of British Space Science*, Cambridge UP, Cambridge, 1986, chapter 3.
2. J. F. Hazell & J. W. Furst, 'Three methods of reducing the impact dispersion of the Skylark sounding rocket'. Paper 70-1375 delivered at the AIAA 2nd Sounding Rocket Technology Conference, December 1970.
3. Documents dealing with the dispersion of Skylark include: WRE Technical Note HSA 105, May 1965 (D. G. Merchant); WRE Technical Note HSA 110, February 1966 (D. G. Merchant & J. F. Teague); and WRE Technical Memorandum 76, May 1971 (J. F. Teague).
4. Reminiscence of Peter Twiss at an interview of 31 January 1985. In more detail, what happened was that after the wind compensation factor had been determined, the order 'Train five degrees right' was given. The operator did just that, but no one realised that the scale on the launcher measured angles in the near-vertical launcher plane, which when projected on the ground plane gave a much greater angle. As a result, the flight path of the Skylark was almost due

north.

5. Unpublished UK MOD data.
6. Project Skylark: Planning Specification WRE 1000, August 1964.
7. G.V. Groves et al, 'Wind and temperature results obtained in Skylark experiments' Paper presented to the 1st International Space Science Symposium, January 1960.
8. Planning Specification WRE 1000, August 1964, Appendices II-IV.
9. Unpublished UK MOD data.
10. This account is based on: 'Skylark rocket tests earth resources survey techniques', an undated press release; M. J. Duggin, 'SL1081 Skylark project: mission objectives and Australian progress report', Mineral Physics Section CSIRO, undated; unpublished UK MOD data.
11. Twiss. One story has it that Long Tom was named thus to placate a Divisional Superintendent who might otherwise have vetoed the project. In possibly sardonic vein, its brother rocket Aeolus also bore the name of a Greek god: of the wind.
12. D. A. H. Bird, 'The Australian sounding rockets Long Tom and Aeolus'. *Journal of the Royal Aeronautical Society* (May 1960), pp. 277-89. The LAPSTAR motor title is derived from 'Light Alloy Plastic', while 'star' denotes the shape of the propellent charge.
13. Although Long Tom had a payload and peak altitude almost as good as those of the early single stage Skylarks (70 kilometres and 150 kilometres approximately) and needed only a short launcher, its peak acceleration of up to 50 g was four or five times Skylark's.
14. Quoted from a contribution by P. H. O. Pearson dated 30 August 1983.
15. Pearson.
16. Project: Upper Atmosphere Research. Trials Wing Planning Specification No. 10, June 1972.
17. Unpublished UK MOD data.
18. Much of the information about Jabiru is derived from a contribution dated July 1981 from L. M. Sheppard.



Night launch of a
Black Knight

21 Black Knight: *The Rocket that Came and Stayed*

OVERVIEW

One warm spring night in 1958 a thunderous roar split the desert silence around Woomera's Launcher 5. The first trial was beginning of a large new rocket, Black Knight, and an impressive sight it made as it rose majestically from its floodlit launching pad and vanished into the moonless sky. Standing 10 metres tall, liquid fuelled and equipped with an elaborate guidance system, Black Knight was by far the largest and most powerful rocket Britain had yet built and sent to Australia for testing under the joint project. To bring this launch to fruition a research and development team 260 strong in two countries had laboured for several years, and the resources of Woomera had been much expanded to cope with it. Fortunately Black Knight proved a great success. Durable and reliable, over the next years it became an excellent test vehicle, much used by scientists probing the secrets of the upper atmosphere. Yet its origins were humble enough and had little to do with the role it later took on, for Black Knight was created as an adjunct to a much more elaborate project.

What had happened was that the engineers had quickly run into unknown territory as they started work on Blue Streak, the ballistic missile designed to be capable of carrying a nuclear warhead across Europe into Russia, so giving Britain the advanced independent deterrent weapon it desired. What they needed was a cheap test vehicle with which to collect data, particularly those concerning re-entry of the warhead into the atmosphere. Black Knight was designed to fill this need. Few other uses were envisaged for it, although the WRE Planning Specification of 1957 did contain a brief note mentioning almost in passing that 'the vehicle may be used to investigate the physics of the upper atmosphere. These tests will be of minor importance.'[1] This last sentence, despite its finality of tone, proved in the event to be far from the truth.

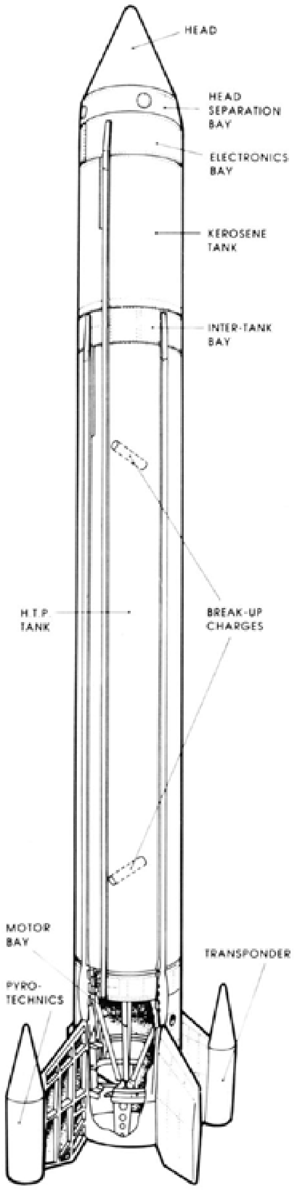
From its conception in 1954 to its first launch nearly four years later, Black Knight demanded a great deal of planning, negotiation with British and Australian ministries and departments, and liaison with the Blue Streak project office and the many contractors who were working on it. The design and building of the rocket itself was only one part of the task. Black Knight was also going to require testing and launching installations in Britain and Australia far more elaborate than anything yet contemplated. But somehow after much effort the project was pulled into shape. The first flight fulfilled nearly all expectations and introduced a triumphant run of successes. Over the next fifteen months four Black Knights were launched, helping to solve some of Blue Streak's problems just as they were intended to do. Several more were in course of production when the blow fell, quite sudden and unexpected in Australia: for a combination of political, economic and strategic reasons, the Blue Streak weapon was cancelled. As soon became apparent, it was to be reborn in the ELDO launcher, but there seemed no hope for Black Knight. Its *raison d'etre* had apparently vanished with the dissolution of the larger project which had brought it into existence. Yet Black Knight's very success marked it out for survival. Its flights had taken it more than 600 kilometres high, beyond the fringes of the atmosphere. Certain findings had been most unexpected and definitely justified further investigation from the standpoint of both pure research and military science. The findings were of no less interest to the Americans, who had a parallel investigation of their own in progress, than to the British; and a co-operative program of further purely experimental flights was speedily agreed to. Thus it came about that Black Knight was saved and transformed into a valuable tool of high altitude research, both in itself and as a carrier of experimental payloads. Right from the beginning Black Knight proved exceptionally reliable, and over the following seven years it built up an impressive reputation. It had its occasional pre-launch hesitancies, but it never failed in the end to lift off and fly. WRE Director Bill Boswell once produced an appropriate eulogy, ‘I have always’, he said, ‘regarded this vehicle as a gentleman.’[2] No fewer than twenty-two Black Knights soared to the edge of space over Woomera and then arched down to smash into the plain down-range, and even after the program finally closed in November 1965 it was not quite the end. Many systems of the rocket and its trappings—engines, tracking and telemetry, radar transponders—lived on in the guise of the Black Arrow satellite launcher.

BLACK KNIGHT IS BORN

We return now to 1955, when Blue Streak was being designed. Its engineers knew only too well that this project was going to push British rocket technology far beyond the prevailing limits, and would not succeed unless a great deal of empirical information was gathered first. Such experimental work and flight testing could be done using a smaller and cheaper test rocket, as long as its performance and trajectory were sufficient to subject the payload to the same punishing treatment as its full scale counterpart. The objectives of the new project almost defined themselves. Broadly, they were to obtain as much practical information as possible on how best to develop a medium range ballistic missile. The largest set of questions Black Knight was intended to answer were those connected with re-entry, which in ballistic missiles reduces to how the descending warhead can best be protected from the intense frictional heat, buffeting and shock as it pierces the atmosphere. The basic requirement, then, was for a rocket large enough to carry aloft a model warhead of 70 kilograms, which would fall back to earth under its own impetus at a speed of at least 1 000 and if possible 19 000 kilometres per hour. (Later heads had their re-entry velocities increased by a second stage rocket motor.) In addition, there were plenty of other problems for Black Knight to investigate. Far too little was known about the stability of a large missile when controlled by rocket jets, or the effect of buffeting during flight on delicate apparatus, or the disruption of radio signals by the electrically charged particles in the rocket efflux. To meet these objectives meant that the Range requirements would be far more complex than anything previously undertaken. The trials teams and Range staff had to familiarise themselves with a brand new set of organisational, handling and safety problems. Black Knight was a big and powerful missile capable of causing a catastrophic accident if it ran out of control.

The first design studies for the new rocket were handled by RAE Farnborough.[3] Even with the constraint that they had to use only familiar technology and British components wherever possible, the engineers still had a number of choices to make. One of the most basic decisions was the choice of propulsion: should the rocket use the reliable and familiar solid propellants, or liquids as Blue Streak was to do? The design of solid fuel motors was familiar, and solid fuels are far easier to handle than liquids. But solid fuels are heavier and give less thrust than liquids, or more precisely less thrust for each kilogram of propellant consumed per second. In the case of Black Knight at least two stages would be needed to give the right performance. Moreover, in those days solid fuel motors needed heavy casings to withstand the pressures generated. To produce enough thrust the first stage would have to be a cluster of three of the most powerful available motors, for time and expense ruled out developing a single large solid fuel motor from scratch. It was the matter of the stability of the ascending rocket that proved the deciding factor. The missile would be held to its course by altering the direction of thrust of the rocket exhaust. This is not easy to do with a solid fuel motor: movable vanes can be put in the exhaust flow, but they give only coarse control, erode quickly and reduce the thrust. By contrast a liquid fuelled engine can be precisely directed by mounting the combustion chambers on swivelling mountings, or trunnions.

Several types of liquid fuel engines were available in 1955. The best choice for Black Knight was Gamma[4], a clever design with an excellent thrust to weight ratio achieved by lightening the components and passing the oxidant through a cooling jacket round the combustion chamber before injecting it. Gamma had been developed at the Rocket Propulsion Department at Westcott in Buckinghamshire for the Blue Steel air-to-ground



The early single stage version of Black Knight. Propellant tanks took up most of the space.

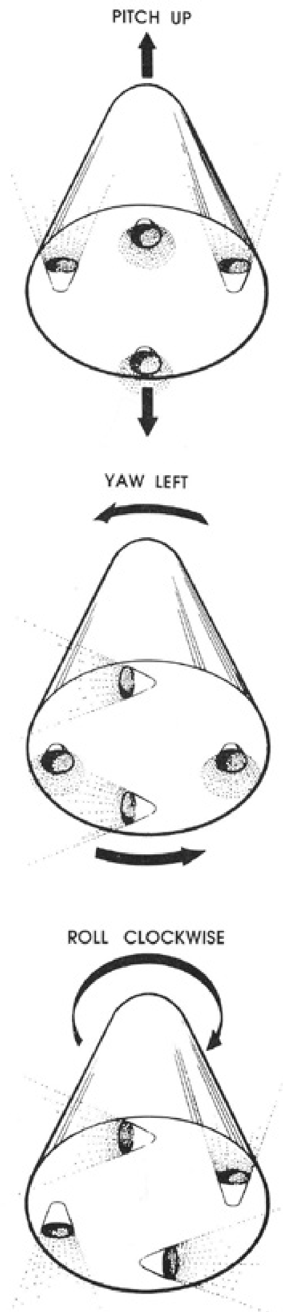
missile, and its propellants were kerosene and HTP. At sea level it produced a thrust of 1.8 tonnes wt. Black Knight demanded far more than this, but four chambers might be combined into one engine, raising the total thrust to an adequate 7.2 tonnes wt. Combining four chambers had a great incidental advantage: if each chamber were on trunnions, six different permutations of thrust direction would give total control over the pitch, yaw and roll of the missile. Gamma 201, as the new engine was called, was designed and built by Armstrong-Siddeley Motors at Coventry in conjunction with Westcott. Though complex in detail the principle of the engine was simple enough. Powerful turbine-driven pumps forced the two propellants, in the ratio of eight parts of HTP to one of kerosene, into the four combustion chambers. The turbines were spun by steam, created by decomposing HTP into steam and oxygen in the presence of a catalyst, a fine mesh of silver threads. In a violent reaction at each chamber head the kerosene was burnt in the oxygen derived from more decomposed HTP, and the escaping hot gases supplied the thrust.

In the meantime work at Farnborough was continuing on the overall design of the rocket. Any liquid fuelled rocket is mostly a pair of thin walled alloy tanks full of propellants which account for nearly all of the launch weight. The first design gave the rocket a stubby shape rather more than a metre broad and 8 metres long, with half the length being the tapering nose cone. The idea was to keep the missile as compact and rigid as possible, because any flexing of the thin tanks made for instability in flight. But the aerodynamics of such a shape were shown to create control problems at low altitude. Eventually four fins were added to the rear and the rocket reshaped to a longer and thinner cylinder which cut the air more efficiently. The fins, fitted with end pods, became useful carriers for external equipment. In this early Black Knight, the 'business' part of the vehicle—the equipment for control, guidance and data telemetry and the associated batteries—took up little room in a bay above the kerosene tank. The rocket body was basically a thin shell, no thicker than the blade of a knife, reinforced with internal framing and bulkheads. The structural weight was only 650 kilograms, but when full of propellants Black Knight's total mass was nearly 6 tonnes. The detailed design and construction was left to the principal contractor, Saunders-Roe Ltd of Cowes, Isle of Wight, a firm later famous for its hovercraft designs. After the contract was let in July 1955, work went forward at an increasing pace and in due course a prototype was ready for testing.

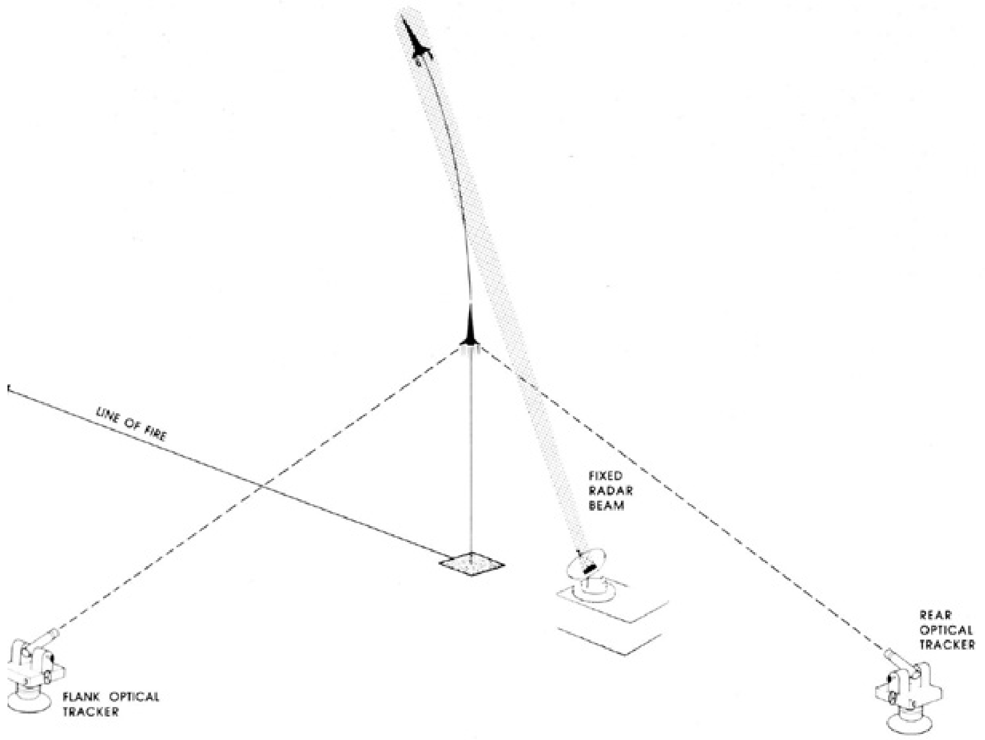
CONTROLLING THE FLIGHT

Black Knight was guided in two ways: by an internal autopilot and by radio signals from the ground. Its autopilot worked on the constant heading principle; that is, the mechanism kept the rocket pointing in a set direction, no matter what forces acted on it to turn it off course or even to topple it. For this to work an internal reference datum was needed by which to fix the exact attitude in space at each instant. Two gyroscopes lying in different planes established a fixed direction, because the inertia of a spinning gyroscope makes it resist forces acting on it to change its position. Thus, as the attitude of the rocket changed, the frame in which the gyroscopes were mounted would move relative to the gyroscopes themselves. This movement was detected and measured by sensors, and the small resultant electrical impulses were amplified and used to control hydraulic actuators powerful enough to turn the appropriate combustion chambers.

So much is easily said. In fact the mathematics and engineering required to achieve this task are profoundly difficult. At every instant of flight the changes in direction of thrust required to set a certain course are constantly varying. Just one obvious factor is that a rocket fully loaded with fuel at take-off has a totally different mass, and so requires quite a different compensation, to one near the end of flight—and this datum is changing every moment. Although various compensatory circuits were used, the design had to remain something of a compromise, to avoid the risk that over-control at any point in flight could drive the rocket into violent oscillation. These complications stretched the electronics of the mid-1950s to the limit, especially when the bulky and delicate valve circuitry had to be fitted in a confined space.



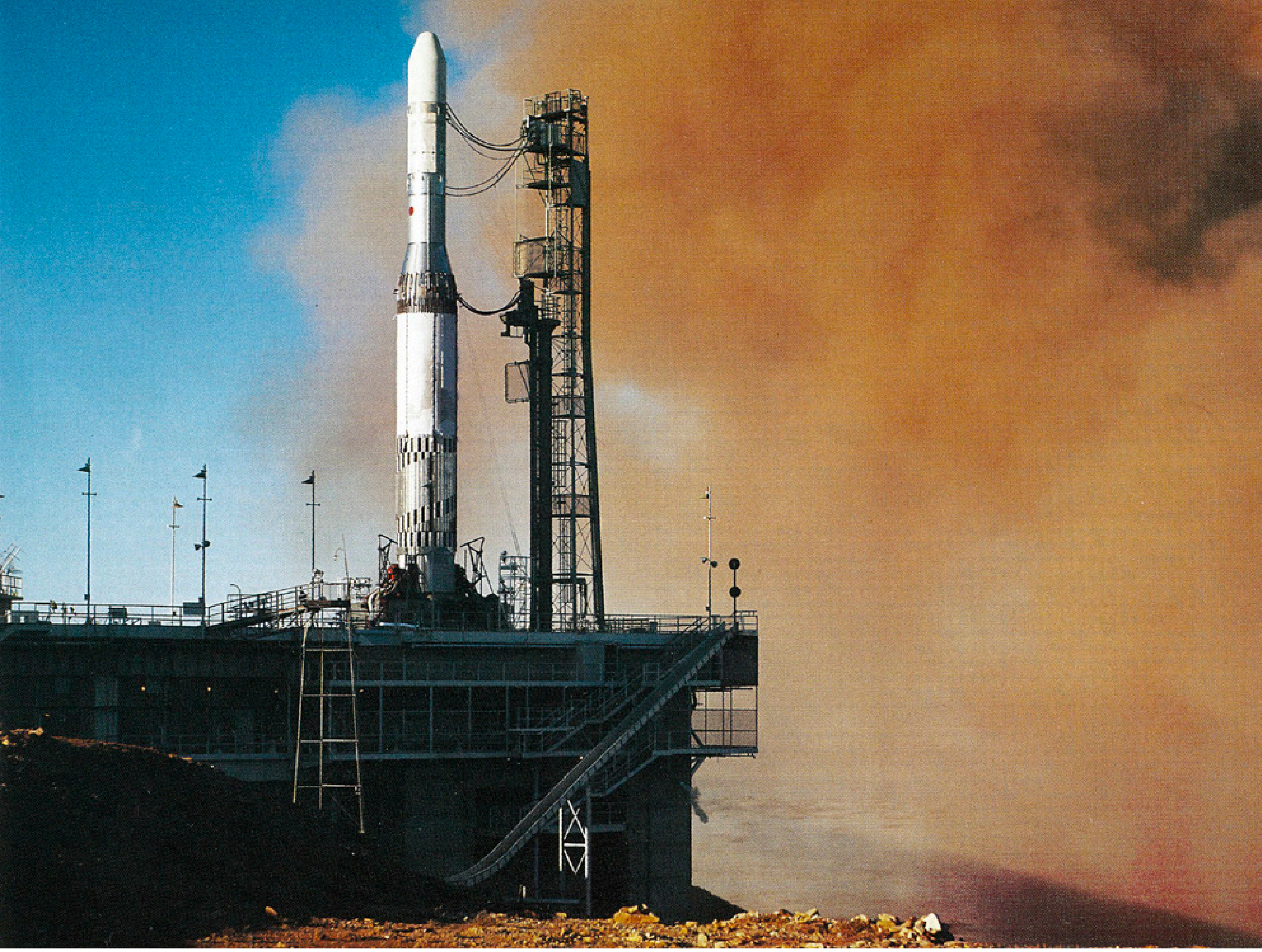
Controlling pitch, yaw and roll of the liquid-fuelled rocket by swivelling the combustion chambers.



Guiding Black Knight during early ascent

Although the internal control system was fairly accurate, guidance from the ground could not be dispensed with altogether. Even the best available gyroscopes could not help but introduce a slight drift in course which, though tiny to start with, might amount over the whole trajectory to an error of as much as 60 kilometres in the impact point. Nor could the autopilot adjust for the effect of cross-winds. To achieve the highest possible speed of re-entry into the atmosphere, Black Knight's trajectory had to be close to a vertical climb and dive. In fact, while its engine was thrusting its line of flight tilted at only 2 degrees giving a planned impact point only 80 kilometres down-range. Once the target area had been selected it was vital that its boundaries should never be crossed, as a mere 80 kilometres to the north-west of Woomera was still well within the pastoral limits. In any case re-entry had to take place in the part of the sky on which ballistic cameras and other down-range instruments were trained. For these reasons Black Knight was under ground control in the initial phase of the flight. The principle of the guidance system, developed at RAE and installed at the Range, was that the rocket's line of flight was marked out by a narrow fixed radar beam, transmitted upwards precisely along the desired pathway. The radar installation stood 200 metres behind the launcher in such a position that, as it rose vertically, Black Knight entered the slightly tilted beam at 5800 metres, some fifty seconds after lift-off. Up to this point two manned optical trackers, each some kilometres from the launcher, monitored the ascent. Their operators had tested the system by tracking a 5 centimetre model of the rocket, tugged by wire up the side of the Guided Weapons building at Farnborough to the distraction of people working in the adjacent offices.

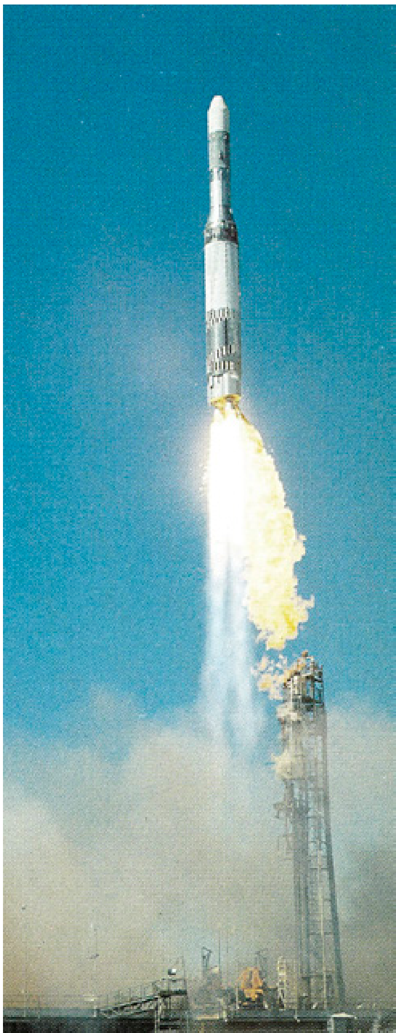
These two measurements of position, whether derived optically or by radar, were displayed for two 'pilots' at a console in the equipment centre not far from the launcher. The operators could issue commands which slightly adjusted the line of flight if an error was developing, up to the time when the engine had exhausted its fuel; in effect, Black Knight rode the radar beam that invisibly marked out its required trajectory. To make doubly sure that the beam was tracked accurately, another observer used a telescope with its line of sight exactly parallel to the radar beam. He used this to watch the retreating jet of flame (which appeared as a point of light) and to fix it in a pair of cross-wires. Thus the guidance operators had an additional source of measurement of the vehicle's lateral movement. These operators bore a heavy responsibility and as human links in an electronic chain they had to be thoroughly trained. They practised for many hours on two flight simulators, one of which was at Farnborough and the other in the equipment centre at Woomera so the operators could sit at the real console used in the flights. They would match their skills against the



A Static firing of Europa satellite launcher F5.

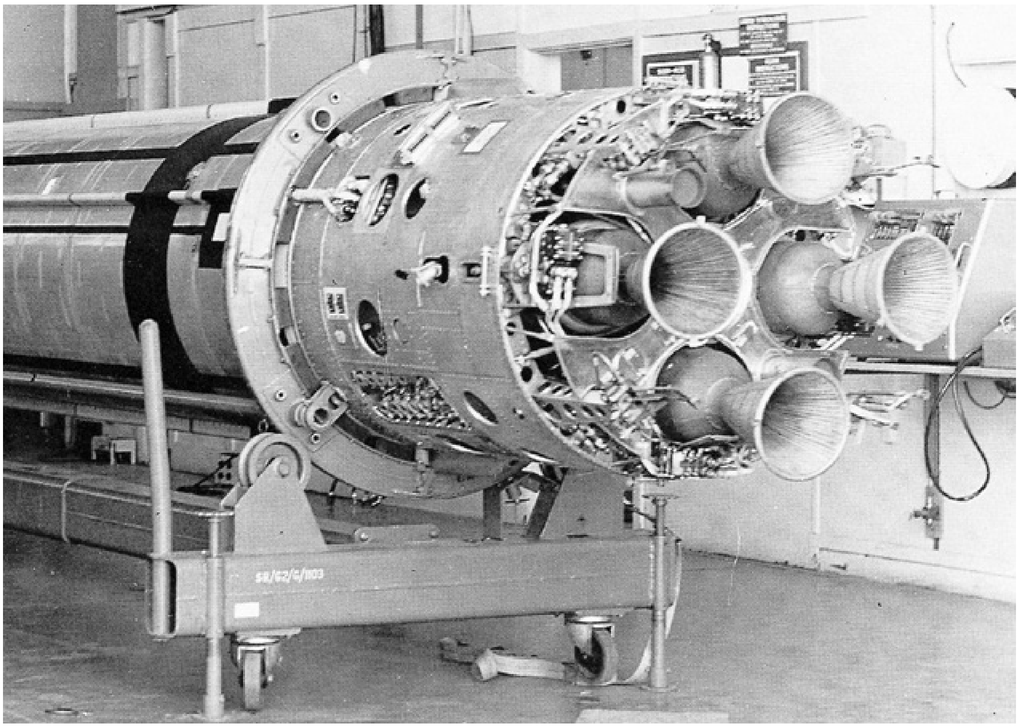
Guidance antennas at the Gove down-range site in Arnhem.

Land Launch of F7.



Insert: The WRESAT display model, exhibited frequently since the launch.

Launch of the US Redstone carrying WRESAT. Australia's own satellite.



The Armstrong-Siddeley Gamma 301 engine, first used on BK16.

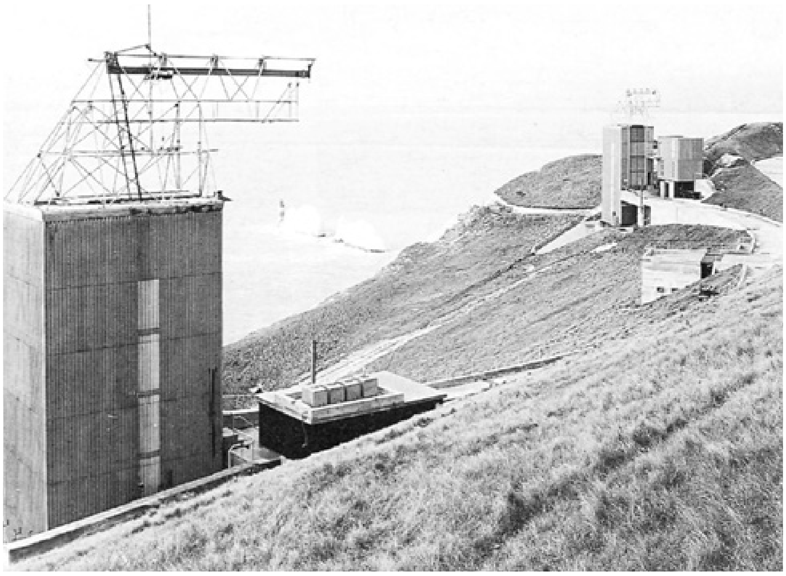
analog computer, which could simulate reality and impose a variety of conditions and surprise events. Eventually, though, the human pilots were removed altogether; the whole ground guidance system was computerised after March 1964, In its first form it was put together very economically. The optical trackers and radar were old government surplus gear; somewhat modified, because their previous task had been to assist in the defence of southern England against the VI flying bombs towards the end of the war.

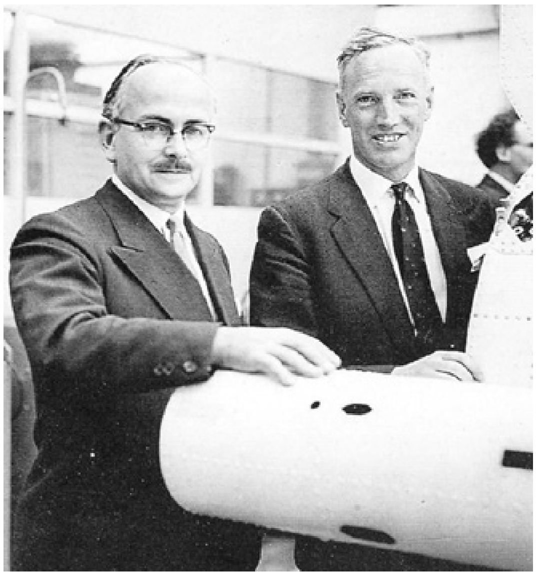
Notwithstanding all the precautions taken to ensure an accurate flight and impact, one further item was necessary as a truly last resort. This was the break-up system, which would enable the Flight Safety Officer to destroy Black Knight should it become uncontrollable. Inside the HTP tank were two truncheon-sized tubes of manganese dioxide, a substance which makes hydrogen peroxide dissociate violently into oxygen and steam. Within each tube was embedded a cordtex charge that could be detonated by remote control, shattering the tube and injecting its contents into the tank. The resulting explosive pressure would break up the rocket so that the components which fell to earth would contain nothing harmful like unburnt propellants. As it happened, the system never had to be used—at least, not deliberately.

As might be expected with a research vehicle, the design of Black Knight changed constantly throughout its life. The re-entry heads were of course different in almost every firing since in most cases they formed the subject of the trial. In later vehicles the propulsion of the heads was boosted by a solid fuel motor, so that Black Knight became a two stage rocket. And in addition to these functional developments, a series of improvements to the basic rocket systems was progressively introduced. A major step took place in August 1962 when the main engine was uprated to a new version, Gamma 301, which incorporated several refinements including in-flight control of propellant mixture ratio, which had previously been a source of some difficulty. At this time, too, a new transistorised autopilot system was introduced.

BLACK KNIGHT IN BRITAIN

Many hands helped to mould the Black Knight project into shape; it owed its success to efficient administration hardly less than to innovative technology. In Britain two private firms and one government body shared the responsibilities of development and production. The plans were drafted and the body built by Saunders-Roe, later to become the British Hovercraft Corporation; the engine was built by Armstrong- Siddeley; and the





Above right: Maurice Brennan (*left*). chief designer of Black Knight, with Paul Leyton, head of the Highdown site. (Topham)

Above: The gantries at Highdown, overlooking The Needles. (Westland Aerospace)

various payloads supplied and the overall management undertaken by the Royal Aircraft Establishment. The plan was for each vehicle to be tested by static firing at a site on the Isle of Wight before it was sent to Australia. Once at Woomera, a team from De Havilland would represent Britain in the launchings under the joint project. De Havilland was the main contractor for Blue Streak and here was an opportunity for it to gain launching experience on the smaller rocket. In the first days, though, most of the activity was in Saunders-Roe's design office in the pleasant yachting town of Cowes on the Isle of Wight. This was where Samuel White, a native of the town, had started producing hulls for the stately flying boats before World War I. Ever since the time when it produced a novel design of gondola for the first Vickers airship, Saunders-Roe had been in the forefront of aviation research and development; and it already had some rocket experience having developed 'cold' rockets, using HTP alone for fuel, as assisted take-off boosters for jet fighter planes. At Cowes the heaviest responsibility for the new project rested on the shoulders of the firm's chief designer, Maurice Brennan, who could list among his successes the Princess flying boat and the Skeeter helicopter. He was a small clever man of dynamic and caustic character who had little patience with those who crossed him. He loved to play up the rivalries between the engineers working for government and private industry. During one debate the pained tones of a Ministry man were heard reminding him that Farnborough was responsible for the design of Black Knight. 'Yes!' replied Brennan triumphantly, 'so it was—and I still have the envelope on the back of which that design was drawn up!'[5]

To avoid transportation problems the static firing site had to be on the island too, in a sparsely settled region where security would not be too difficult and the least damage done to the rural scene. The area chosen was less than an hour away by road, on the western tip of the Isle. Bearing the appropriate name of Highdown, this was a place above the white cliffs overlooking The Needles, jagged spurs of rock reaching out to sea; a place long feared by mariners but then as now a popular tourist haunt. Highdown was owned by the War Office, and they leased it to the company. Already standing on the site was a useful fort, one of a series built round the Isle in the sixteenth century to deter French invaders. It had been modernised in Victoria's day, only to languish unused under its local name of 'Gladstone's Folly'; but the foresight of that Prime Minister had been vindicated somewhat in World War II, when the fort's defenders were able to loose off rounds occasionally against German motor-torpedo boats. Now it was adapted to a thoroughly modern purpose, its spacious and dry cellars being turned into an equipment centre housing the many consoles of the test gear. In this scenic place high above the sea great chunks of chalk cliff were gouged away to accommodate the gantries, six storeys high. Two firing sites were built 90 metres apart on either side of the blockhouse, one as a back-up in the event of the other's destruction by fire or explosion. Great exhaust ducts, shaped like the elbows of a giant's plumbing system, served to bend the exhaust jets through 90 degrees and out across the sea. From his vantage at the tip of The Needles the lighthouse keeper had a spectacular view of the firings because he looked straight up and into the mouths of the ducts as they vomited steam and fire; he was the only outside witness however, for shipping was kept clear and the area sealed off from the public. Sixteen years were to pass before visitors could again stand on the cleared clifftop and absorb the glorious seascape. Later the National Trust acquired it.

While Highdown was being prepared, work went forward on the Gamma engine at Armstrong-Siddeley's works at Ansty near Coventry, and on the guidance and command link systems and the payloads at Farnborough. The organisation was therefore complicated. Seven places of work in two countries and four different sets of people were intimately involved: the design office at Cowes, the works at East Cowes, the firing site at The Needles, the engine design and test site at Ansty, the RAE at Farnborough, and WRE at Salisbury and Woomera. Somehow all the pieces of the jigsaw had to slot together at Woomera. Many others had a supporting role: the Ministry of Supply in London, the Ministry's representatives in Melbourne and their UKMOSS organisation at Salisbury, and last but by no means least the Australian Department of Works which in the eighteen months or so available had to translate the plans into concrete and steel. The links between these various organisations were largely maintained by a quartet of personalities. At RAE, Harold Robinson, a former Whitworth Scholar who had been involved with Black Knight from its conception, represented the British design authority. WRE's man in London was Jeff Heinrich, previously with Missile Projects Group at Salisbury and later to command the Range during many of the Black Knight trials. From the other direction came 'Mac' Powell, seconded from RAE to liaise with WRE. At Saunders-Roe the principal link man was Bert Lloyd, who stayed with Black Knight right through the program and through that of its successor, Black Arrow, too. Lloyd was a calm unflappable man rather older than the average, who well filled the role of mentor to the younger engineers. Despite his stock warning to the keen innovators—'you'll be hoist with your own petard!'—in fact he was hoist himself when, realising the importance of disseminating decisions promptly, he started to put out his own unofficial minutes of the lengthy progress meetings. These bore the caveat 'the official RAE notes will be issued at a later date' and so they were; but sometimes it was very much later indeed, and Lloyd's self-imposed task became a permanent chore. Such were the link men who, on many liaison visits to Australia, helped to acquaint the Establishment with exactly what was required to get Black Knight off the ground.

H. G. R. (Harold) Robinson.

Bert Lloyd. (Westland Aerospace)

Up to this stage the De Havilland company was not involved, but as it was to supply most of the firing team in Australia it was now time to introduce the new men to the system. Some of them went to Farnborough to work on the guidance and in-flight command link systems. Others went to the Isle of Wight to work with the Saunders-Roe team at Highdown. Saunders-Roe would only send a small group of six or so with the rocket to join the Woomera trials team. De Havilland would also have a team based at Salisbury to carry out the installation work at Woomera under instruction from a small Saunders-Roe team of engineers, also resident at Salisbury. Armstrong-Siddeley would send one or two engine technicians with the Saunders-Roe team from Highdown, where they had a permanent representation to assist with the firings on the static site.

The fact that the launchings at Woomera were to be conducted by De Havilland was most discomfiting for Saunders-Roe. Having designed, built and tested the missile the company's men naturally believed that no one could possibly be better qualified than they to oversee its firing. They were jealous of the fact that De Havilland at this early point knew little detail about its design or about its ground installations at Highdown and elsewhere, although they knew of course that a re-entry test vehicle was being built to help solve the Blue Streak problems, and that they were to use the trials as a training exercise. For their part, the Saunders-Roe men could see only too clearly that they were getting into a no-win position: a successful firing would reflect very favourably on the De Havilland trials team, whereas any failure could be made to reflect on them as designers and builders, and to the discredit of their company. The potential for friction was great. So in March 1957 a meeting of the two companies was called to hammer out the differences in the patrician surroundings of Ryde's Royal Squadron Hotel, where Queen Victoria was wont to rest on her travels to and from Osborne House. On this day the usual atmosphere of somnolent calm was rudely disrupted. Emotions ran high; both sides gave vent to some blunt speaking before Guy Gardner, De Havilland's Chief Designer, took a firm grip on the proceedings and came up with the right and memorable image. 'During the Black Knight program', he said, 'Saunders-Roe and De Havilland have got to stand shoulder to shoulder and the flags will fly at exactly the same height!'[6] This notion found general appeal and the meeting broke

Jack Redpath (*left*), Stan Joyner and their wives at a celebration of the first Black Knight launching. (Adv)

up in a mood of bonhomie which was sustained and transformed into a common loyalty to Black Knight itself. Jack Redpath and Stan Joyner, the two key company representatives in Australia, were determined it should be so, and on the rare occasions when discord did occur they moved quickly to remedy it; but no doubt success oiled the wheels of human relations since no need arose for recriminations about the rocket's performance.

AUSTRALIA PREPARES FOR BLACK KNIGHT

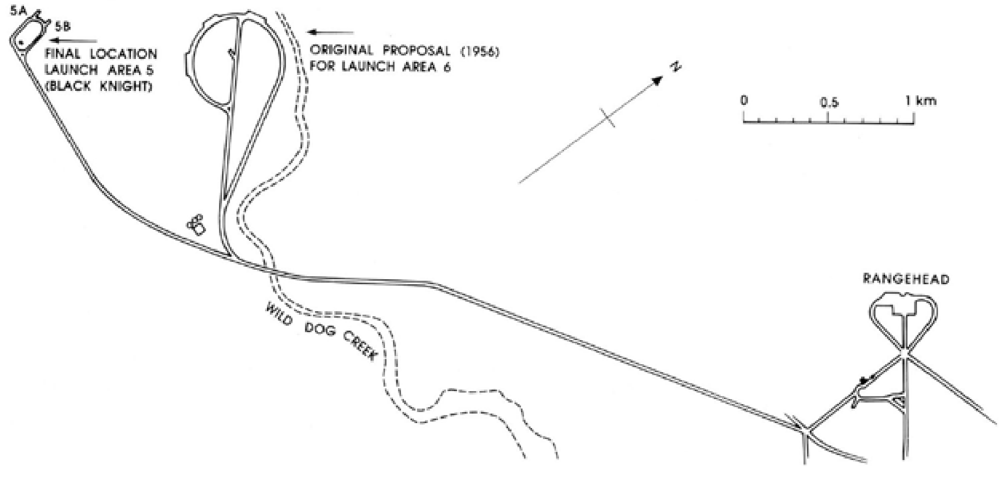
H .J. (Horrie) Higgs.

By early 1955 the first ideas for the new ballistic missile installations were arriving at WRE. The original plan was for Blue Streak and Black Knight to be launched from a single integrated site, and though this was eventually dropped in favour of two distinct sites many kilometres apart, it clouded thinking during the year when Salisbury was confronting its prime task of finding and developing a suitable area. Considerations of safety were very much to the fore. Black Knight posed more of a threat over a wider area than any other rocket yet fired. Naturally the Establishment had strong views on this subject, and they were put by the jovial Horrie Higgs of Missile Projects Group in a series of papers issued from June 1955.[7] Higgs foresaw that Black Knight would be too big to bring out to the launcher fully prepared for firing. Much of the final assembly would have to be done on the spot, which therefore had to be readily accessible. For this reason he dismissed the suggestion that the launcher ought to be another 32 kilometres north of the rangehead to give the village an even greater margin of safety. All he had to go on was old information about the V2 and figures on the explosive power of TNT, but he used them to argue convincingly that the integrated launching site need be no more than 3.5 kilometres from the rangehead, with the nearest buildings (apart from a blockhouse) no closer than 1.6 kilometres. At these distances the operation control room, with its communications, flight safety and telemetry equipment, would not be imperilled even by a rocket running amok immediately after take-off, because the engine could be shut down in time. He thought that a useful site might be found about 6 kilometres from the rangehead in the upper reaches of Wild Dog Creek, where a natural dip in the land would offer some protection from blast. Here three launchers could be erected 300 metres apart, each with its own preparation tower so that work could proceed independently on separate rockets. Heated discussion followed these proposals, with liaison visits from Farnborough which went on for some months. The Ballistic Missiles Division of RAE added the details that each launcher pad should be a surface of thick concrete on which the rocket would stand over a water-cooled duct to receive the exhaust blast. Before launch, a retractable gantry would surround the rocket, protecting it and giving servicing access. Only 150 metres away a blockhouse, with a concrete roof 2 metres thick and capable of taking the full force of the rocket toppling back from a low altitude, could house a small team in charge of the guidance and launching apparatus. The Instrumentation Building and Test Shop 2 at the rangehead already existed to supply their special facilities.

The instrumentation was to be elaborate. Two separate telemetry receivers at the rangehead would collect data from the rocket itself and the nose cone. There was also to be a collection of fixed ballistic cameras, kinetheodolites and radars at the launcher and at the impact zone, a circle 64 kilometres in diameter. None of these extra details conflicted with the proposals of the remarkably prescient Higgs, and his scheme was largely adopted.

So much for the requirements, but who was going to pay? In distributing the costs between the partners the broad principles of the joint project might have been expected to apply; namely, that Britain should pay for the rockets and its accessories, while Australia should make available the Range, its instrumentation and the other specific needs on the site. WRE and its agents had to prepare the launch areas, build the blockhouse and supply the propellants, which in the case of HTP would come to some 9 kilolitres a month. The impact zone had to be prepared, and some contractors' quarters supplied at Salisbury. Even a first estimate put the cost at around £850 000. Speaking for WRE, Controller H. J. Brown entertained no doubts that this expenditure was worthwhile for Australia. He noted that 'these trials . . . will fulfil the primary objects of the Joint Long Range Weapons Project, commenced in 1947, towards which the main range development has been directed',[8] by which he meant the evolution of the device originally code-named Menace, the long range, cruise missile capable of carrying a warhead across Europe. Brown, of course, was thinking of Black Knight as no more than a small component of the Blue Streak program.

However, this was close to the time when, in May 1956, Britain and Australia were about to renegotiate the financial basis of the joint project; broadly, the question was being taken up again of who should pay for what, recognising that Britain was about to embark on a series of extremely expensive projects which would require elaborate new Range facilities, particularly the massive installations planned for Blue Streak. Australia made no bones about refusing to start the civil engineering work for Black Knight, when the outcome of the negotiations might be to reduce its share of the costs. Indeed, Australia first asked Britain for cash on the table if it wanted the work to begin, promising to reimburse its partner later if required to do so.[9] Fortunately this rather painful state of affairs was resolved by the Erroll Agreement, which put a ceiling of £9.5 million annually on Australia's contribution to the entire joint project. This Agreement included a policy statement on 'deterrent weapons', as Blue Streak and its adjuncts were known: 'the Commonwealth Government accepts the proposal by the UK Government for the carrying out of a programme of deterrent weapons testing in Australia'.[10] But by the time the Agreement was signed work had already begun in earnest at Salisbury and Woomera; the Australian government, buoyed up by a British guarantee to cover the cost if necessary, allocated £138 000 to Black Knight. By mid-June the Principal Officer of Missile Projects, Jeff Heinrich, reported[11] that work had started on the launch area 5.6 kilometres southwest of the rangehead, consisting of two launching pads 90 metres apart with the protected equipment centre 200 metres away, forming the apex of a sharp triangle. At this time the idea was for a single ballistic missile launching area, and the layout drawing showed the Blue Streak launcher only 1.3 kilometres away, closer to the rangehead.[12] (This plan was abandoned soon after, and the giant launchers for Blue Streak



Location of the proposed area for launching ballistic missiles.

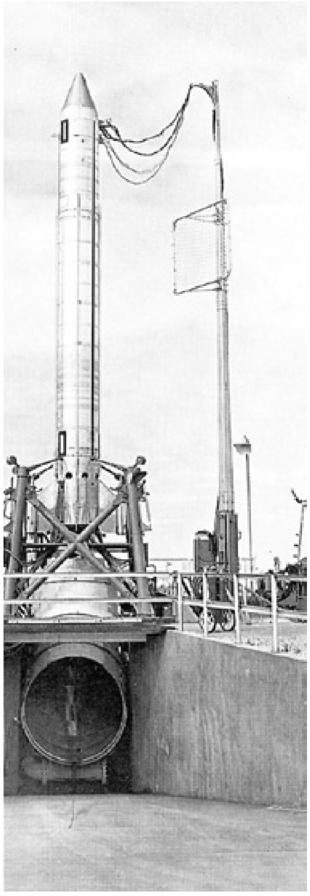
were finally built 12 kilometres away on the edge of Lake Hart.) The first updated estimates described the launching facilities at Woomera, including remote instrumentation posts, with some Salisbury extensions, and mainly covered the initial construction and services work which was to be contracted to the Department of Works.[13] The list was detailed and lengthy. It included all access roads, fencing and guard houses, concrete foundations for the launchers and numerous instrumentation posts, the equipment centre and associated buildings, electrical power, and water supplies for blast duct cooling and fire-fighting. The cost amounted to £833 000. Extra communications, new instruments to track the flights, and tankers to handle the propellants brought the costs past the million pound mark—more than ten million in 1986 dollars. The next few months saw intense activity in heavy construction work at the Range, mostly by the Department of Works, for the first Black Knight firing remained scheduled for only a year ahead. At the same time the rocket was being built and tested in Britain, so continual liaison between the two countries was essential. Jeff Heinrich was posted to London as the permanent WRE representative, and technical missions came to Australia at about three-monthly intervals. A small committee of five men, representing WRE, RAE and the two principal contractors, was set up to look after the construction work at the Range, running so informally that it was often called 'the coffee shop'. Later its meetings evolved into a more formal but still small committee known as the W1 Panel, which controlled the trials facilities throughout the Black Knight program.

By the end of 1956 good progress had been made at Woomera and the launching area was visibly taking shape.[14] The access roads were already usable. The first launcher pad was down, together with its underground concrete bunker or 'test post', where the cables, piping and launching supplies to the rocket would be concentrated. Two hundred metres away stood the concrete monolith of the equipment centre and in the distance tanks held 180 kilolitres of water for duct cooling and emergencies. Sites for the instrumentation had been chosen and surveyed, and WRE was building the devices to go there. Nevertheless, despite this progress it was becoming clear that the sheer complexity of the job, as well as delays in production in Britain, meant that the deadline of July 1957 for the first launch could not be met. Back it went to November, then back again to April 1958. These delays were not exactly bemoaned at Salisbury as the special instruments were proving tricky to develop. T. F. C. Lawrence, Superintendent of the Systems Assessment Division, expressed the general sentiment in a message he sent to Heinrich in London: 'we will not complain . . . we will not make our sigh of relief public'.[15] During 1956 much of the structural steel work—the gantries, launchers, umbilical masts—were designed by Saunders-Roe and manufactured by subcontractors around Portsmouth and Southampton. By the end of the year many components were ready for shipment to Australia. The following March the first gantry, weighing 42 tonnes, was shipped from Britain on schedule and arrived at Port Adelaide in knocked-down form. Unfortunately the parts had travelled as deck cargo, and the markings put on them in white paint to aid assembly had worn off; even worse, some of the members, having survived the voyage unscathed, slipped out of their bundles while being unloaded and, according to the stevedores, sank without trace in the murky waters of the harbour. But luckily the gantry was a simple design. The rear part was a lattice of girders forming a tower through which stairs ran to each of the six working levels. This tower supported a forward enclosed housing which fitted closely round the rocket, a floor at each level fully surrounding it and permitting several men to work round it simultaneously. This housing was an upright box of corrugated steel and perspex, with pairs of doors at each level. When these were all opened, the gantry could enclose or be withdrawn from the rocket, moving to and fro along a short track on its four sets of bogie wheels, the rear ones containing the 80HP electric motors which propelled the whole structure. Once this platform had been set up on its rails, it was easy to spread all the other parts out on the ground and put it all together like a giant Lego set. A team of five put both gantries together in five weeks, replacing the missing parts from local sources. The top roofed level was built on the ground and then raised by crane: the sole subcontractor, Perry Engineering, made it look easy. By this stage Australia had done nearly all of her share. Buildings, test posts, gantry rails, water and power—all were in readiness.

THE WOOMERA INSTALLATIONS

The headquarters of the Black Knight team were set up in Test Shop 2 at the rangehead. This was a T-shaped building. In the leg were the storerooms, laboratories and offices, and in the head was the preparation area with an overhead crane running its full length. Here the rocket was received. The airframe, engine bay and payload arrived on cradles inside cases, from which they were lifted and mounted on wheeled frames for movement around the Test Shop preparation area. After testing the engine and rocket body were fitted together, lifted on to the missile transporter and taken to the launcher. The two sets of transport cases were shuttled across the world many times.

Out at the launcher site only Launcher 5A was totally finished. Although 5B was commissioned as well later on, to begin with 5B was built without its electrical systems and then removed to a distance and anchored in a safe place, to serve as standby in the event of a fire or explosion at 5A. At 5A the exhaust duct was the first thing to be installed—a concrete pit with an open concrete channel to deflect the exhaust gases through a right angle and into the open air. Water at the rate of 9500 litres a minute was pumped through slots around the duct to prevent its steel lining from melting. Over the duct rose the launcher stand, mounted on four pads sunk in massive concrete foundations. Into the stand went the release assembly: two hydraulic jaws which held the rocket firmly until the moment of launch, while an anti-torque device prevented its rotating since it had to be launched with its axes in a set position. Four arms protruded from the top of the launcher, engaging slots in the rocket and holding it vertical: at take-off, counterweights in these arms pulled them upright to clear the emerging vehicle. While it was on the launcher undergoing last minute checks Black Knight, like any large rocket, was entirely dependent on a multitude of outside supplies. Its powered flight lasted just a little more than two minutes. Its electrical supply was a fixed quantity stored in batteries and had to be conserved; and the propellants, loaded on board in a precisely calculated amount, could not be used before the launching sequence began. Many services, then, had to be supplied at the gantry: HTP to start up the turbines of the propellant pumps, hydraulic fluid for the actuators, compressed air for the internal bottles which kept the tanks pressurised as the propellants were sucked out, freon to keep the electronics cool before take-off, nitrogen gas to flush out the pipes, electricity, lighting and fire-fighting services, HTP and kerosene propellants, gear for defuelling, and the emergency dumping system for getting rid of the HTP in a crisis. The power for the rocket was supplied through an umbilical mast and connectors, which were ejected at launch as the mast automatically swung clear. All services to the gantry were fed through heavy ducting from the subterranean test post, and they went via 'break points' as the gantry was mobile and removed from the launcher before a firing.



Looking into the exhaust duct of Launcher 5A. Black Knight BK01 sits on the launcher stand, held vertically by the four release arms.

The power came from the equipment centre, which housed all the measuring, monitoring, recording, firing and guidance equipment. To this place also came information on Black Knight's pre-flight condition along more than seventy electrical channels. Under the control of an operator was the motor control console, the guidance console, telemetry consoles and display unit, plotting table, control and computing racks, command link transmitter, servo test gear console, sequence selector and the sequence operator's console. This last piece of equipment was programmed to run through the final sequence of events up to and including firing automatically, and was timed to run in parallel with the main Range timing system to give a common time to all launching and Range operations equipment.

Intense concentration at the motor control console during the BK25 trial in 1965.

RANGE INSTRUMENTATION

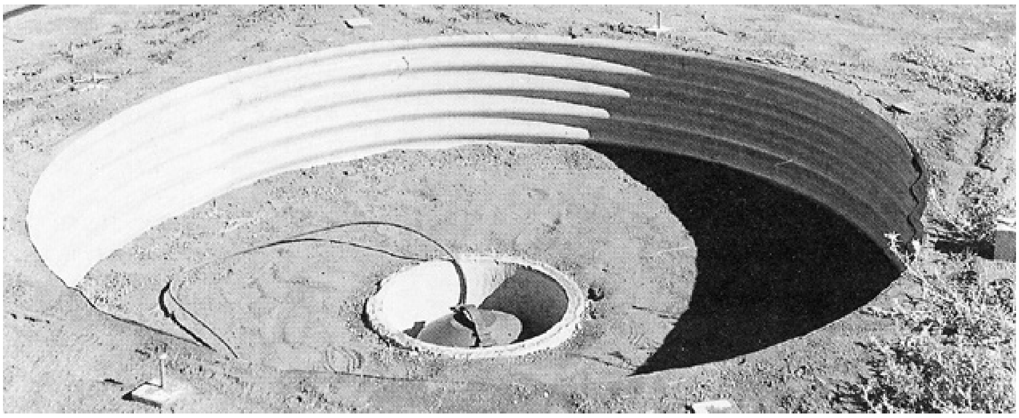
Apart from the guidance and radio command systems which were really part of the rocket and therefore a British responsibility, all the ground instruments to monitor the flights of Black Knight were supplied and installed by WRE. These instruments[16] had two major functions: first, to furnish a detailed permanent record of the rocket's internal operation and trajectory from before lift-off to impact; and second, to provide instant information during the flight for safety reasons. In both cases information from the guidance system played its part in building up the network of data. While many of these instruments already existed, other important systems such as the ballistic cameras and the digital impact predictor, were developed specially for Black Knight and the prospective Blue Streak trials.

An array of fixed and tracking cine cameras was used to give a film record of the behaviour of the rocket during its launch and ascent, a film that would be studied intently after the trial, particularly if the rocket had misbehaved in any way. Many of these behaviour cameras had been installed in the launcher area specially for Black Knight, while the cameras covering the later flight were part of the normal Range instrumentation. During the preliminary static firing, five nearby cameras photographed engine ignition, the movement of the combustion chambers and the readings of pressure gauges connected to the rocket engine. During the launch, five other Vinten cine cameras mounted on the launcher apron photographed Black Knight as it rose slowly from the launcher, and also recorded any tilt or roll after the jacks released their hold. All these cameras were unmanned as they were unprotected and well within the danger area, so they were oriented beforehand and turned on and off remotely. The nearest manned cameras were two manual tracking Vintens some 2 kilometres away, one on either side of the launcher, and they tracked the early ascent. The Contraves kinetheodolites also tracked the ascending rocket while its engines were firing. Their film records showed not only its behaviour but the azimuth and elevation angles too, from which the trajectory could be computed later by triangulation.

For reasons concerning optical instrumentation Black Knight was launched after nightfall, so in order to capture every detail of the crucial first seconds of liftoff the launcher was floodlit. The film showed the whole rocket while it remained within the range of the floodlights, but after that the image was only of the four jet flames, which gradually merged into a single dwindling point of light and finally vanished altogether when the propellants were exhausted at a height of about 115 kilometres. But after the engines closed down Black Knight continued to coast up to a peak altitude of 800 kilometres, and its track during this coasting or ballistic phase had to be accurately determined. The solution was to install ballistic cameras at several dispersed sites.[17] The use of these in the Black Knight trials has been fully described in Chapter 14. To support these ballistic cameras, the kinetheodolites used on the ascent were switched on again for the re-entry of the head. They rarely succeeded in locating it at first, as it was a race against time for the operators to find and train their narrow angle instruments on the glowing head before it extinguished. There were other events competing for attention, particularly the much brighter re-entry of the main stage. Great efforts were made to provide useful acquisition aids for the Contraves but they were too coarse and inaccurate to be really effective until later in the program, when the kinetheodolites were put under the control of the radars until the operators observed re-entry in their telescopes. Then they took over manual control and tracked the glowing head to extinction.

So much for the visual record. During every moment of its flight Black Knight was also sending back a copious flow of information about its internal state, by two or three independent telemetry transmitters working on different frequencies. The information could be varied to suit the purpose of the trial, but it always included data from the major systems of propulsion, guidance and control, together with measurements of acceleration and temperature, and occasionally of vibration as well. To receive and record these transmissions WRE operated receiving stations in the Instrumentation Building, at Mt Eba (later at Mirikata) and sometimes at Salisbury. The equipment received and decoded the incoming signals, making a permanent record on paper charts and magnetic tape.

After each firing as much as possible of the wreckage—and particularly the precious re-entry head—had to be located somewhere within the 300 000 hectare circle of the impact zone. The flight safety measurements should have revealed the general location, but extra help came from five sound-ranging microphone arrays spaced around the perimeter of the zone. These picked up the sonic boom of the incoming head and from the separate recordings



A sound-ranging microphone in its pit.

the point of impact could be calculated—or that was the theory. In practice the calculation was easily upset by wind and took too long to compute—or so it seemed to the impatient Recovery Officer. Later a special Polaroid camera, devised by Murray Ziesing of WRE, helped retrieval. Up to six of these tough, foolproof devices with fish-eye lenses were placed around the impact zone on posts whose positions had been exactly surveyed. Each camera gave a view of the sky from horizon to horizon, and with a time exposure photographed the streaks of light from the descending fragments. From these permanent records the re-entry point was determined by triangulation.

The instruments used by the Flight Safety Officer (FSO) formed an integrated system in its own right, except that it took up data from the guidance system to duplicate its functions and thus increase its reliability. The FSO had the unenviable responsibility of destroying a straying rocket, taking the decision on the basis of evidence offered to him electronically on video screens and plotting tables. The first anxious moments occurred right at the beginning of the flight, when the nearby equipment centre and rangehead buildings were in greatest danger if the rocket malfunctioned and fell back. For the first 6 kilometres the flight was closely observed by operators at three 'skyscreens': wire screens with limit lines marked on them to allow direct reading of the flight path. In the first seconds two of the skyscreens had the direct power to destroy, but after that they could only advise the FSO who reacted as required. In the later stages of flight the FSO continued to make use of the guidance system, but supplemented its data with more from another source: four of the optical X-trackers that formed part of the Missile Tracking System (MTS). The FSO saw the results drawn on large plotting tables, showing him where the rocket was each instant and warning him if it were likely to cross the safe impact boundaries. The X-trackers and guidance radar assisted him during all the powered flight and a little beyond it; but during the last seventy-five seconds before the engine cut off the FSO would have the advantage of yet another display: the 'walking impact point' shown automatically by a moving pen on a large scale map of the area. It was information critically important to the man with his finger on the destruct button, who would have to press it if there was any risk of the rocket crashing outside the Range boundaries.

FIRST FIRING APPROACHES

Zulu Squire being prepared for firing.

The early months of 1958 saw great efforts by the teams in both countries to have everything ready by the launch date—still set for April. The prototype Black Knight had been waiting in Test Shop 2 since the previous August, ready to be installed on the launcher and used by the trial team for a full dress rehearsal of the procedures up to lift-off. The Range teams were equally intent on joining the rehearsal to ensure that their many responsibilities such as propellant handling, high pressure gas supplies, cooling and fire-fighting water, could all be operated perfectly under real trial conditions. Flight safety was vitally important too. In order to give practical experience to the isolated groups of tracker operators posted about the Range, WRE had arranged a series of firings from Area 5 of a little liquid fuel rocket called Zulu Squire, designed to simulate a real launching.[18]

At RAE Bob Reeds, a meticulous engineer of the Black Knight group, had been working for months with a small De Havilland team, writing a complete set of instructions on precisely how each rocket preparation task should be carried out. At the start of the trial, over 260 separate 'Contractor's Standard Procedures' (CSPs) had been completed.[19] Similarly, WRE produced written instructions for the duties which the Range staff would perform. In Reeds' own words:

> I think I am right in saying that BK was one of the first missiles handled by RAE which required written trials preparation procedures. Previously, any suggestion that trial teams needed written prompting was regarded as an insult—but of course many a missile failed miserably because of elementary forgetfulness in the stress of the moment . . . The idea of CSPs was received with some scepticism, and many people scoffed at the idea of trying to prepare a missile with large volumes of paper in their hands. I always thought that one of the greatest benefits that came out of CSPs was that people had to think in advance about what they had to do, and then could do it again in the same way if necessary.[20]

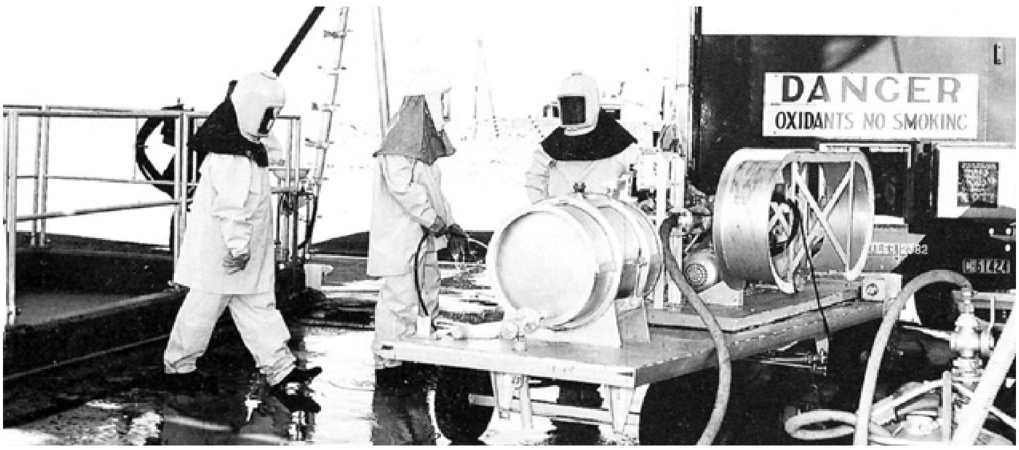
Unfortunately, but perhaps not unexpectedly, a number of troublesome problems arose as the first Black Knight and its ground installations passed through their final tests. At Highdown a minor accident during a test-firing damaged the engine pipework and electrical wiring, which had to be rebuilt. A persistent malfunction in the autopilot occurred, which was eventually traced to a peculiarity of the gyroscopes and led to changes and delays.[21] At Woomera, a defect appeared in the HTP start-up system for the engine, and the fire-fighting system would not work properly.[22] And finally there were delays in shipments to Australia. After a series of postponements the launch date was set for a moonless night in the middle of August 1958.

This later date was helpful in some ways, less so in others. In February WRE had taken delivery of 5 kilolitres of HTP in expectation of an April launch.[23] Stores of this unstable fluid had to be checked every day, and there was always the risk of spillage. On the unprotected skin HTP produces severe blistering like a bad burn and at the launcher a plunge bath was always ready for the immersion of anyone who received a splash. De Havilland supplied safety clothing, consisting of proofed overalls, spaceman-type helmets and plastic boots. The last item was hard to find in Britain. One potential supplier had his problems, which he struggled mightily if incoherently to express:

> PVC Vinyl Boot: Prototype in size eight only until moulds were ready in all sizes which takes months. However, a delay has occurred from the official side on colour and size rools. We have three pairs exact as sample sent February 11th. These have inside boot lefts and rights exact as we did for a fair quantity for the Ministry of Supply all size eight outsides PVC one foot. We offer these boxes at £4 per pair.[24]

One-legged men could be fitted at once; two-legged ones would take longer.

From April onwards, the trial teams from RAE and the main contractors were beginning to assemble in Australia. Harold Robinson arrived from RAE to take charge of the trial, accompanied by Bill Arklay as his assistant. In all the Black Knight team had sixty-seven members.[25] Early in July, rocket BK01 reached Woomera by air in a Bristol Freighter and went at once to Test Shop 2, now buzzing with activity. All was ready for it, but the moonless nights of August still slipped away as last minute troubles were ironed out. The static firing of the engine took place on 2 September and was successful. Then, with everything ready for the launching sequence, the weather turned sour and for five days the team watched the sky anxiously for signs of a break in the cloud. It cleared on 7 September 1958, and at long last the launch could go ahead.



Protective clothing used when handling unstable HTP oxidant.

BLACK KNIGHT'S ACHIEVEMENTS

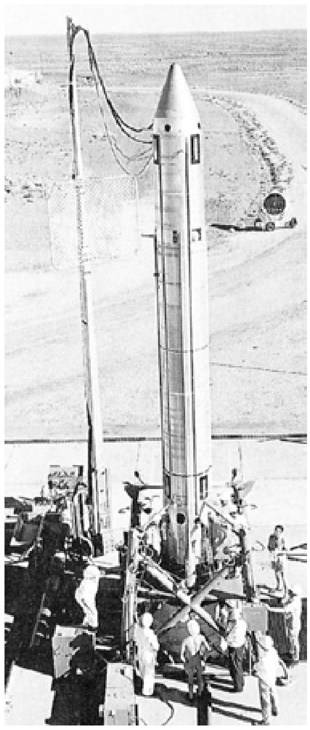
The first flight of Black Knight, designated BK01, was the moment of truth for the trials team and Range staff. Besides the obvious strain of attending the climax of several years of design and construction, those present had an extra reason for being tense. BK01 was not a typical first trial. The usual procedure in testing rockets was to check the performances of the various subsystems such as engines, guidance and control in a progressive series of separate flights. But this was not done with Black Knight. It flew for the first time as a united whole, except that the re-entry head contained an extra batch of measuring instruments to record the flight performance and so did not separate from the body at high altitude. Not surprisingly, therefore, the adrenalin flowed freely around Launcher 5 on the evening of 7 September 1958 as the critical moment approached. But all the last checks looked good; the main engine ignited on schedule and at three minutes past eight o'clock Black Knight rose smoothly into the starry sky. One of the skyscreen operators produced an almost poetic description:

> At approximately +4 seconds a grey cloud of steam or smoke began to mushroom from beneath the missile, growing in size and density till it completely obscured the vehicle. Because of this I did NOT see the round move from its launching pad, nor did I have any idea of its original behaviour. It was an anxious few seconds and then at an altitude of approximately 100 feet with the count nearing +10 the ghostly grey nose of Black Knight began to arise from amid the smoke. Very slowly at first did the missile lift itself away, but true as a die and with increasing acceleration did it follow its intended trajectory . . . The final observation I made was at approximately +640 seconds; a brilliant flash appeared on the horizon at a bearing from my post of possibly 340°, accompanied either before or just after by a booming roll of thunder. Illumination brilliant in the early stages. Searchlights valuable, in so much as they created an artificial moonlight effect.[26]

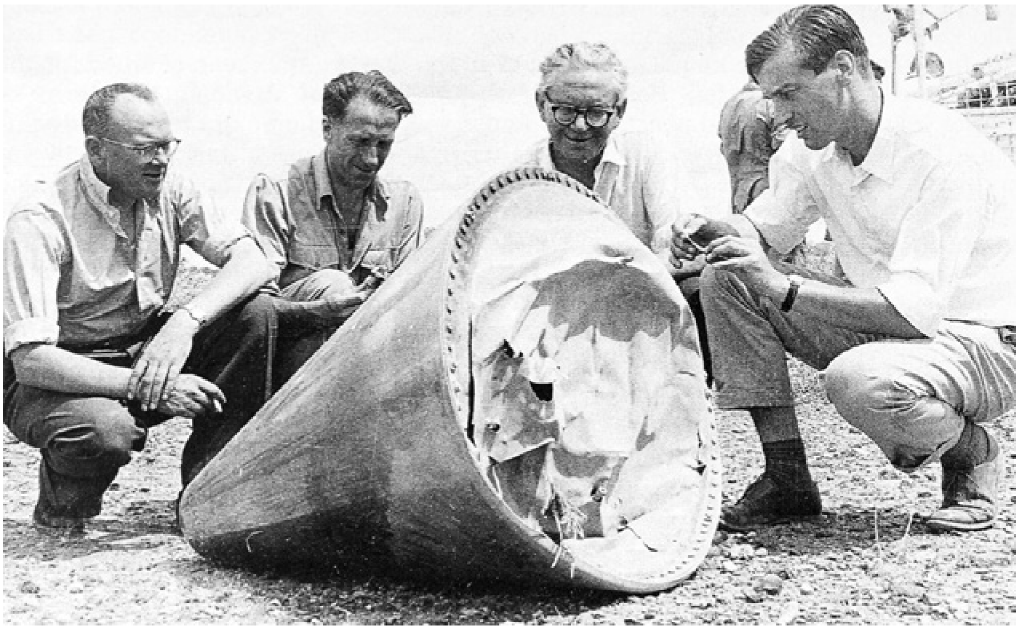
Great jubilation followed this apparently flawless launch, although the records showed that while the rocket had displayed perfect stability and the guidance had been effective, the engine for some reason had closed down a little early at a height of 60 kilometres, perhaps following an explosion. This had to be investigated. Nevertheless, at the first post-flight meeting Harold Robinson found general assent for his summary that 'the departure from the old guided weapon technique of piecemeal development has paid off'. Congratulations poured in from all quarters including the Supply Ministers of both governments. An enthusiastic leader in the Melbourne Age spoke of the new rocket as being not merely an item of military research but an instrument with which to explore space. It was, it said, 'a heart-warming achievement . . . which has set the imagination of the world alight'.[27]

Still basking in the warmth of congratulations, the teams looked carefully into the premature engine cut-off. The fault was not in the engine itself, for it had provided nearly perfect propulsion right to the end. But the telemetry records held a clue: the signals from the transmitter in the rocket body had ceased abruptly at cut-off, but the transmitter in the head had sent data for another six minutes, although not from the sensors in the rocket body. An explosion breaking the rocket into two pieces explained the data, and confirmation came with the discovery of the debris—the two main sections had hit the ground more than 17 kilometres apart with a scattering of fragments in between. It was now evident that an electrical fault had operated the flight-destruct system, for no signal for destruction had been transmitted from the ground. The break-up system employed two separate transmissions, with the reception of either one being enough to trigger the explosion. One signal passed to a special radio receiver and the other via a coded signal was received by the radar transponder. Although it was never conclusively proven to be at fault, the latter was probably responsible. As a safeguard it was replaced by a second command receiver, and the fault never recurred.

Preparations now centred on the second Black Knight vehicle, BK03. (BK02 was used at Highdown). This firing was a repetition of BK01, again with a head which did not separate. When it was launched on 12 March nothing untoward occurred except that the engine compartment overheated somewhat towards the end of the powered flight due to lick back of the flame. The high temperature caused a vapour lock in the kerosene fuel lines, cutting off the supply and thereby causing a final period of 'cold' burning when HTP alone provided the thrust—particularly galling for the man responsible, Leslie Parkin, whose urge to get the most out of a rocket engine bordered on the fanatical. Nevertheless the rocket rose to a



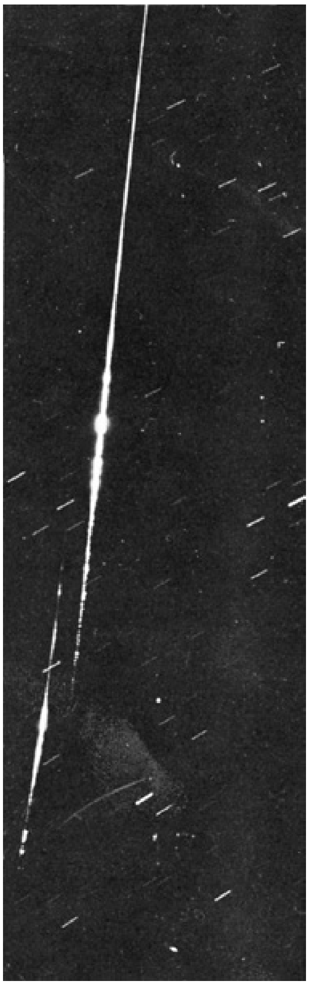
Preparing the second Black Knight, BK03, for firing. The Equipment Centre is visible in the top left.



Bill Arklay, Les Parkin, Bill Williams and John Anderson (*left to right*) examine the ' non-separating' head of BK03 after impact. It broke off during ascent.

peak height of 540 kilometres before turning earthwards, and the flight was also a success for the guidance telescope, used on this occasion because its accuracy as an alternative to the radar had been demonstrated at the previous firing.

The program to test the performance of the re-entry head now began in earnest. Three more Black Knights were launched in 1959, each with a nose cone which detached and entered the atmosphere separately. The design and construction of the heads, which differed according to the purpose of the experiment, were under the direction of Rolf Ulrich, a German rocket engineer who had joined RAE at the end of the war. Two types of head were used that year to discover how the heat of re-entry could best be withstood. The first type was a cone of mild steel intended to absorb the heat by its sheer ruggedness and thermal capacity. The second type relied on ablation: its upper part was made of asbestos-resin, a tough non-metallic material which charred and burnt slowly away, absorbing heat energy in doing so, while the lower part was of stainless steel. Additionally, each head carried sample patches of other ablative materials such as graphite to get further information on the re-entry effects. All the heads carried complex instruments: gyroscopes and accelerometers to measure motion, thermocouples to measure temperature, and, in the ablating head, a device to measure the rate of erosion. The data were sent by telemetry in the first two heads, but BK06 carried a miniature tape recorder in a protective capsule able to withstand the violent re-entry and the great impact with the ground. The capsule was ruggedly made of steel, surrounded by thick asbestos- resin; inside was another box containing the recorded tape spool, which was the only essential part.



The re-entry of BK06 head (upper streak) and main stage (lower), photographed by a fixed camera at the launcher. The short trails are from stars.

Making the heads separate cleanly and fully from the body was a tricky problem.[28] When the main propulsion ceased, an inertia switch detected the end of acceleration. After a brief delay, two explosive bolts released the head and a set of springs pushed it gently away. The cone then had to be tipped downwards, and this was done by tiny solid fuel jets attached to its surface which, in sequence, tipped it over, stopped its turning at the right moment, and then spun it like a top to keep it stable on the descent. The system was an unqualified success on BK04; the steel cone re-entered at nearly 13 000 kilometres per hour and survived intact. On flight BK05 the head did separate properly, but the rocket was still accelerating and banged into it from behind, breaking a telemetry aerial. Data were lost, but the cone was recovered bearing evidence that its ablative coating had reached 1200°C. Before the next flight, BK06, in October, the timing of the separation sequence was adjusted and also the delicate protruding aerial was missing as a recorder was on board. The launch and flight were perfect but it happened again: at a height of 105 kilometres a gentle collision occurred, enough to topple the head during re-entry. Although the tape recorder worked correctly, and even recorded the bump, its data were of little value. The head tumbled so erratically that nothing could be learnt about its attitude at a given time. The re-entry effects were deduced instead from ground photography and an examination of the cone material.

A CHANGE OF DIRECTION: PROJECT GASLIGHT

It was plain that the first five launches had revealed some teething troubles, although the rocket itself already had the makings of a safe and reliable launcher. Also the experiments so far had revealed something new: the brightness of the light and comet-like trails emitted by the re-entering heads in the upper atmosphere had been immensely greater than expected, and were well worth further investigation. Moreover, the WRE radars had observed an enormous echo from the ascending and descending rocket caused by a cloud of ionised particles around it, particularly as it passed through heights between 250 to 400 kilometres.[29] At their Atlantic Missile Range the Americans had already observed similar high altitude phenomena. Besides their intrinsic interest to physicists, they had great military implications both for defence and offence. For defensive purposes, the echo might permit the detection of a missile launch at extremely long range, and analysing the light from the ion cloud behind the head might allow one to distinguish between a descending warhead and a decoy. Offence demanded the same knowledge, to be applied in the opposite direction: it was important to discover which materials and shapes had the least echo, and how the decoys re-entering with the warhead could best be made to mimic the appearance of the real thing.

In September 1959 the Deputy Controller of Trials, Arthur Wills, had discussed the matter with the American Advanced Research Projects Agency (ARPA), and had received an enthusiastic assurance of ARPA's collaboration in a further program at Woomera.[30] At this time ARPA was funding a large research program into anti- ballistic missile systems. Not that it believed a really effective missile interception system was possible with current technology. It was almost sure it was not possible. What it wanted was to satisfy itself that there were no undiscovered phenomena of re-entry on which the USSR might build an effective anti-missile system, thereby disrupting the West's deterrent policy. Naturally it was nearly as difficult to prove that an effective system could not be developed, as to develop one. The scale of the effort in this direction was such that the team working on Project Gaslight, and its successor Project Dazzle, at Woomera was one of more than fifty groups working in various places on optical measurements alone. The particular appropriateness of Black Knight for such experiments lay in its separating head. This meant that its distinctive trail could easily be distinguished from the clutter of the disintegrating rocket. Moreover, a more advanced two stage Black Knight was almost ready, one where the head would be forced back into the atmosphere under the power of a small separate solid fuel motor, greatly increasing the re-entry speed and allowing it to be tracked and recorded in isolation. The ground instruments had a very narrow field of view.

The three nation Gaslight program quickly got under way. By March 1960 a mass of American equipment had been installed at the Coondambo and Parakylia ballistic camera sites.[31] This new gear—photometers and radiometers—was designed to measure the radiation from the re-entering bodies in the ultra-violet, visible and infra-red wavebands. At this stage Gaslight was no more than a sideline, the main object still being research work for Blue Streak. But the situation was about to be transformed. BK08 was sitting on the launch pad when the news of Blue Streak's cancellation broke. As it happened Gaslight and Dazzle guaranteed a future for Black Knight, but for a while the cancellation news produced great uncertainty among the team. Just when their rocket's new role of investigating the radiation effects of re-entry had gained international support, it seemed that its career might be ended. Still, the next Black Knight was being prepared for launching, its objectives were defined, and there was every reason to go ahead.

This trial, BK08, employed the first of the two stage vehicles. The second stage was really a nose cone about 3 metres long containing Cuckoo, a small solid fuel motor, with the re-entry head attached below it. At separation time, jets of high pressure air lifted the whole cone off the main body and spun it for stability as it coasted up to the highest point of the trajectory. The Cuckoo motor still pointed nose downwards and as the separated stage was descending from high altitude it fired, increasing the speed of the head through the atmosphere by some 6500 kilometres per hour and producing a total speed more comparable with that of a Blue Streak warhead.

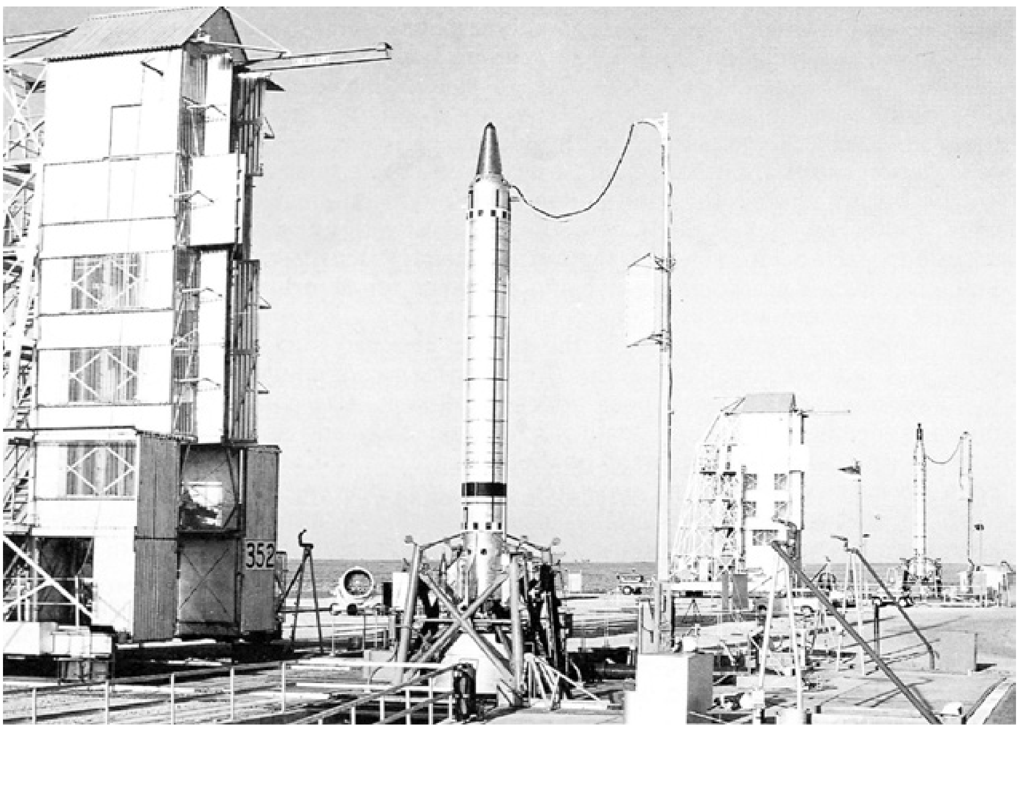
Unfortunately on this occasion Black Knight was less of a gentleman than usual. Rolf Ulrich, the designer of the re-entry heads, was in charge of the trial and to his chagrin the launching preparations persistently went awry. He had the engine test-fired nine times before he was confident of its perfect performance, and twice the actual launch was postponed: 'we are at the end of our wisdom with this most unfortunate vehicle,' the despairing Ulrich telexed back to RAE in his idiosyncratic but expressive English. When BK08 did lift off on 24 May all went well at first, proving that the new shape was completely stable; but then through a trivial fault the second stage of this troublesome rocket did not separate and the whole thing entered the atmosphere as one piece. However, the identical BK09, launched a month later without bother, amply made up for this disappointment. The head was an ablating type of asbestos-resin, constructed in a new segmented way. It survived a re-entry speed of 16 500 kilometres per hour and a temperature of 1700°C presenting the Gaslight observers with spectacular radiations for subsequent analysis[32] until its segments disintegrated some 9 kilometres up.

BK07 followed in July, a single stage vehicle with a mild steel head of an unusual 'heat shield' shape. The front of the head was crowned by a mushroom-like cap, 63 centimetres in diameter, for protection against re-entry heating. The head separated from the main body, rose to 530 kilometres, and re-entered the atmosphere nose first; not quite at the correct attitude but sufficiently so to demonstrate that the heat shield was effective. A telemetry sender was carried in the head, and worked so well that complete measurements of its temperature and motion were received.

Ken Smith of RAE. He took a leading part in several Black Knight Trials.

Gaslight continued early in 1961 with two further trials, BK13-14. On this occasion the two rockets were prepared simultaneously so that both firings could take place within a fortnight. The urbane and imperturbable Ken Smith of RAE took charge of this stressful operation, and by the first week of February two Black Knights were erect on their adjacent launchers, the first and only time that this occurred. BK13, one of the last single stage vehicles, was launched on 7 February. Its flight was very successful and the separated head, made of stainless steel with an ablating cone, provided excellent photographic and radiation records.[33] However, Smith's efforts were largely wasted, for the hopes of launching BK14 shortly afterwards were not realised. An engine problem appeared during the test-firing which caused a long delay. The rocket was eventually launched in May, followed by BK17 a month later; both were two stage vehicles, but in neither case did the second stage separate properly.

It was now obvious that system improvements were necessary, and as their design was already progressing it was decided to relax the launching schedule in order to incorporate them. This would also give more time for detailed analysis of the Gaslight data obtained from the six firings (which included the powered ascents as well as the re-entering heads and rocket debris) and to plan the extensive future program of re-entry physics experiments which was already being considered internationally.

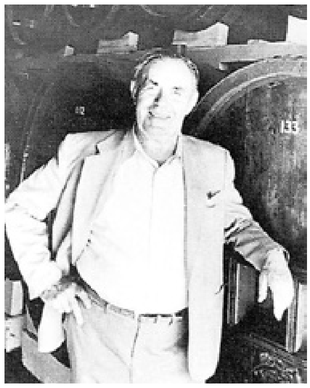


BK13 (*left*) awaits the launch while the two stage BK14 sits on Launcher 5B.

INTERLUDE FOR THE TRIAL TEAMS

By this time trials duty for the team members had developed a routine. While a launch was being prepared the concentration and the stress were intense. No one bothered much about ordinary working hours or stopped for lunch if there was any impending problem; to save time an amateur barber even gave haircuts on the launcher pad. Only after the launch—especially after a successful one—did relaxation come, and then it was total. The trials team, the Test Shop personnel and the Range staff returned to the village where the contractors laid on lavish mess parties. When the Britons had recovered, they returned to Adelaide for a short holiday before the long flight home. After eight or nine tense weeks at Woomera with little privacy or time off, Adelaide seemed blissfully civilised. Invariably a barbecue hosted by the genial Hermann Thumm was arranged at the Yaldara Winery in the Barossa Valley, where the lush scenery lay softly on eyes accustomed to desert harshness. About the only sore point was the rates of pay which some of the British received from their government for trials duty at Woomera. The contractors' staff were quite satisfied, for their employers took the liberal view that a sensible man ought to be able to show a small profit for a stay in Australia; it would be the hope of a small reward that would sweeten labour. This generous spirit did not permeate government circles and the RAE men received a meagre subsistence allowance at Woomera. In 1961 it was only five shillings a day plus accommodation paid, whereas the contractors' men were getting seven times as much. This was so inadequate that some of them undoubtedly returned home financially worse off than when they left; and this could happen several times since most of the team made more than one Woomera visit. Overtures were made at various levels to have this anomaly removed but the Ministry remained obdurate, taking the view that the absence of the breadwinner ought to mean savings in his domestic economy; hardly consolatory since some crises of family life could prove expensive if he were away. The only compensation was that the RAE men were treated generously at the bar by their sympathetic colleagues.

All in all, though, Black Knight was a great booster of morale. Its flights touched the public imagination with the romance of rocketry, expressed in vivid colours in the closing pages of Ivan Southall's popular Woomera, published in 1962. The Woomera of a future day had already started to appear in science fiction novels.[34] Now the long and successful run of Black Knight raised the reputation of the town even further at home and overseas.



Hermann Thumm at his Chateau Yaldara winery.

Some British members of the trials team: five De Havilland, three Saunders-Roe, one RAE.

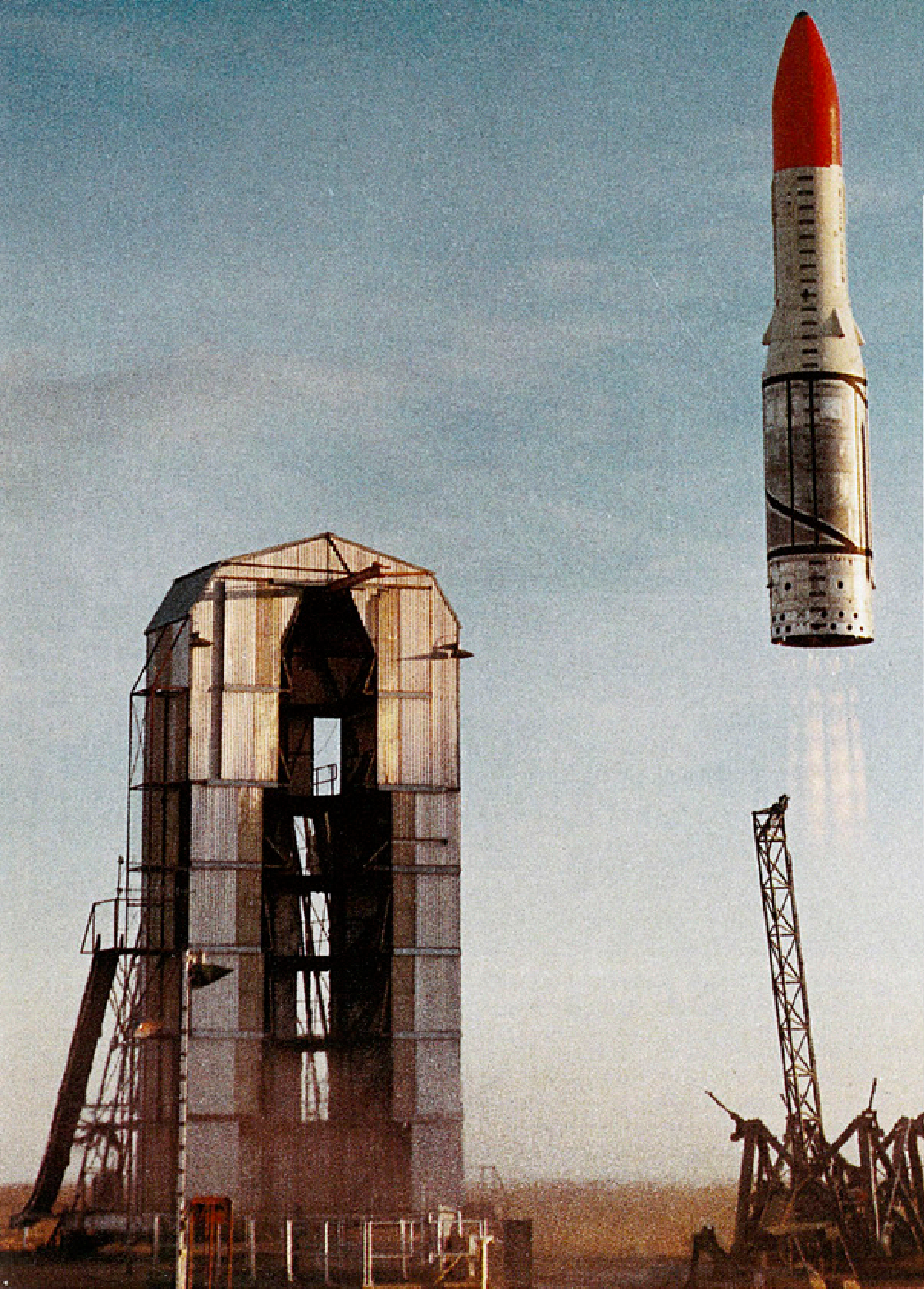
COMPONENT TRIALS: SAFETY AND INERTIAL NAVIGATION

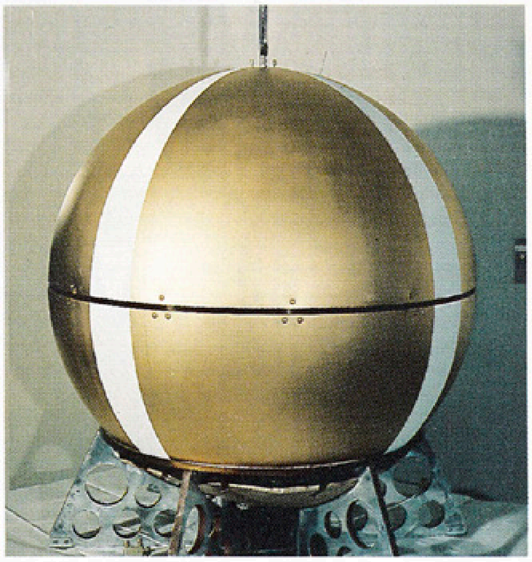
It may be recalled that, apart from probing the performance of the re-entry head, Black Knight's job was to flight test some of the Blue Streak systems. This objective was not neglected, although it was rather overshadowed by the intriguing findings of the re-entry program. From 1958, two different series of tests were carried out, and they accounted for a great deal of work and expense over the following two years. The first system concerned flight safety. With the advent of an intercontinental missile of Blue Streak's size, safety became a paramount concern; the Range authorities wanted the system thoroughly tested well in advance, and Black Knight was the rocket to do it. As it passed across inland Australia, transponders in Blue Streak would be tracked by the FPS-16 radars at Red Lake and Mirikata. Then there was the command break-up system WREBUS, which depended on several ground transmitters with duplicated receivers in the rocket for redundancy and reliability. Finally, Blue Streak would use a new high capacity telemetry system and, although it was not concerned with flight safety, this also required testing and was a link in the equipment chain. All three of these systems, transponder, WREBUS and telemetry, would be fitted with all their power supplies and antennas into a cylindrical cone-topped capsule, mounted as a plug-in unit at the nose of Black Knight. In flight, the equipment would all be actuated (though WREBUS did not of course trigger an explosion), and its performance telemetered to the ground. Work was proceeding on this and Launcher 5B was being prepared for the first trial when the news of the Blue Streak weapon cancellation came through. Work on the capsule continued with low priority while the future use of Blue Streak as a satellite launching rocket was determined. It was more than three years before the trial was resuscitated during the preparation of Blue Streak as the first stage of the Europa vehicle. BK11 carried the capsule in October 1963 under the charge of Bob Reeds, who had been associated with its design from the start, and it was so successful that a second capsule held in reserve with BKIO was not required.

The second component trial was very complex, and concerned the testing of an Inertial Navigation System (INS). Blue Streak, a medium range ballistic weapon, could not use Black Knight's simple system of an autopilot with initial ground guidance; not when its designers, pursuing the requirements of the military strategists, wanted to be able to explode their warhead close to a defined and distant target. The heart of the INS was a central platform freely mounted on 3-axis gimbals and controlled by gyroscopes in such a way that its attitude relative to the stars remained fixed, no matter how the rocket moved and turned. On the platform, accelerometers were mounted to measure acceleration in any direction, which by a simple computing process could give a continuous record of the exact position of the rocket in space. Every component was of the highest accuracy available, and the INS was extremely costly compared with the relatively simple Black Knight autopilot, which could not adjust for sideways drift.

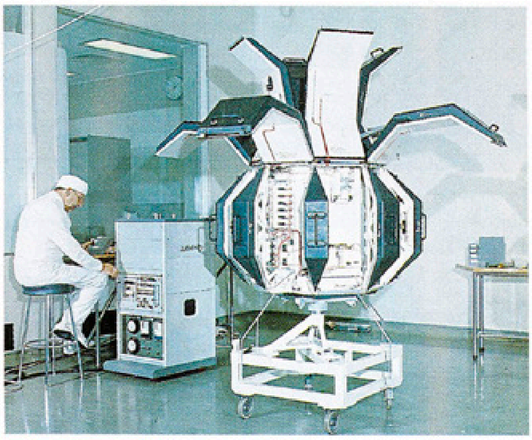
The effects of rocket flight on such apparatus are very difficult to reproduce on the ground. Acceleration of a constant value and direction cannot be applied to a gyroscope at all, except for a few seconds outdoors on a rocket sled. The Black Knight trials offered a means of testing the INS under real conditions. Once again the whole apparatus was fitted into a self-contained capsule, a fibreglass cone- cylinder shape 2 metres long, attached to the rocket nose.[35] But internally it was far more complicated than the safety capsule. It contained the inertial platform -with its many ancillaries and also, mounted on the platform, two television cameras peering upwards through toughened glass windows in the cone. Their job was to transmit back their view of the starry sky in space. If the platform operated correctly the star pattern should always appear perfectly stationary. The INS measurements of the rocket's position in its flight were transmitted back by telemetry, to be checked against the known trajectory derived from the ground ballistic cameras.

Designing and building the INS capsule was contracted to Smith's Aircraft Instruments of Cheltenham, and work began early in 1959. The program of flight trials was to begin in mid-1961 and continue over several years with approximately twelve firings, since a general research effort on inertial navigation systems was planned. WRE had been aware of developments from the outset, but in October 1959 Ken Smith, then responsible for the capsule engineering at RAE, led a mission to WRE to discuss the ground systems in detail. The new installation work at Launcher Area 5 was quite extensive. The inertial platform had





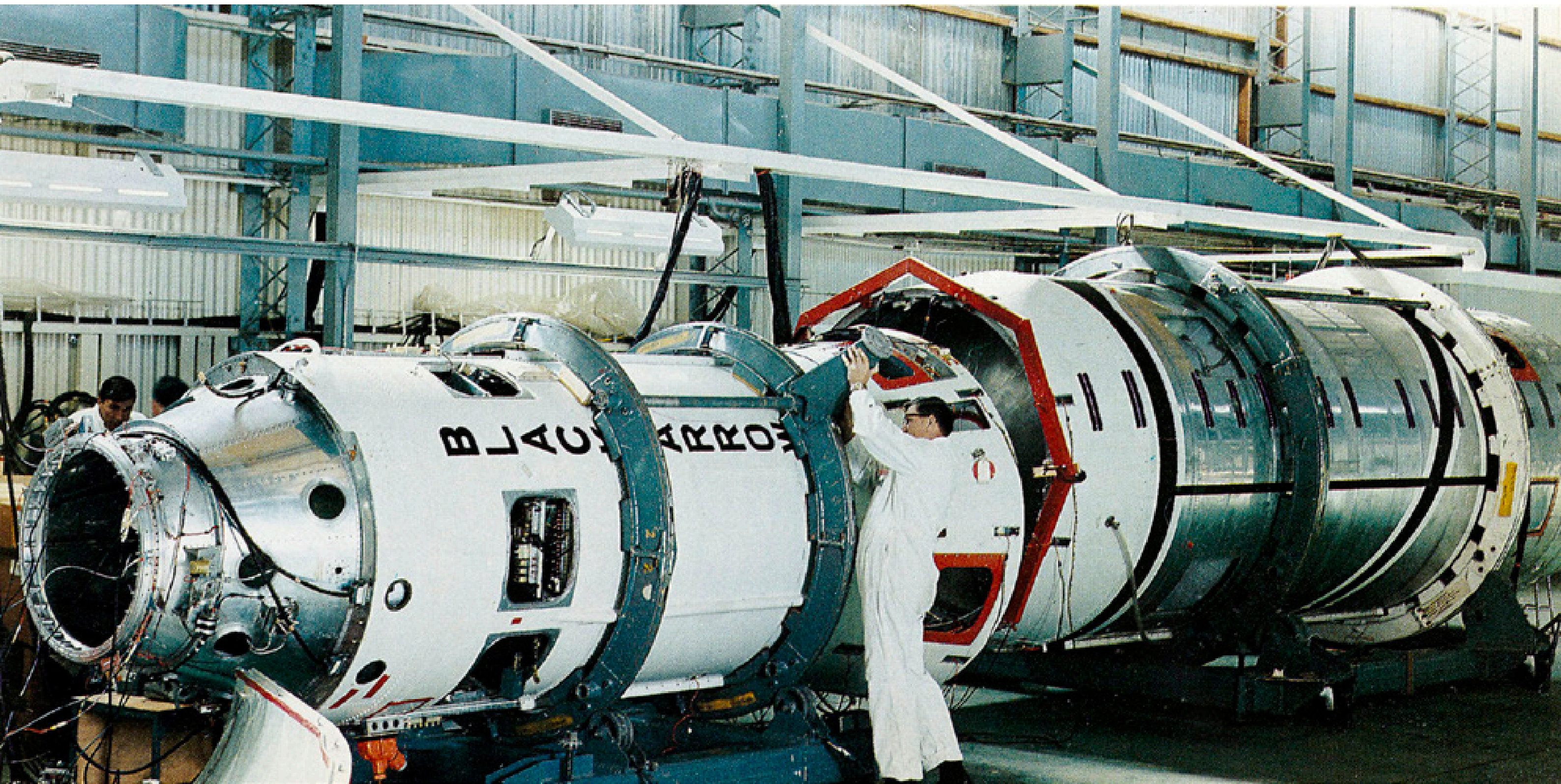
Orba, the unsucessful golden ball satellite.



Black Arrow R1 is launched on a long trajectory leading to the Indian Ocean.

Black Arrow R2 in the test shop.

The Prospero satellite in the spotless cleanroom at Test Shop 4. Launched in 1971, it is still in orbit.



▲ UK veterans of the joint project at a valedictory luncheon at the Naval and Military Club, Piccadilly, on the day the project ended, 30 June 1980.

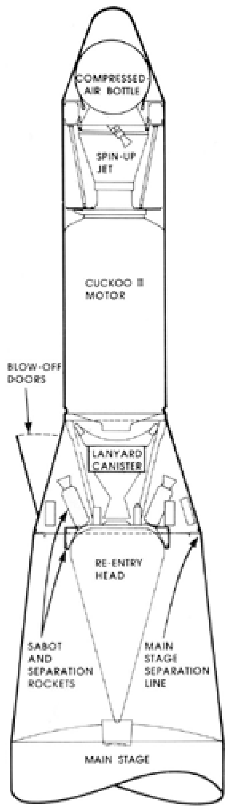
▼ An archaeological remnant of Woomera's heyday: the ruins of LA6, the Europa launcher apron.

Back row left to right: Messrs D. A. Arnold; W. T. S. Pearson; F. H. East CB; D. Lane; S. B. Jackson; W. D. Brown.

Front row left to right: Air Cdre N. H. Fresson DFC; Col. J. A. Caddy; Lt Gen Sir John Evetts CB c b e MC; Messrs N. Coles CB; S. A. Hunwicks, OBE; G. E. Hicks. (Irvin Airchute)

to be aligned before launch by means of a projected beam of light, accurate to five seconds of arc, and the optical equipment had to be mounted on two rigid, unshakeable concrete plinths sunk deep into bedrock, A closed circuit cooling system was to be installed in the 5B test post, to maintain the capsule internal temperature constant within 1°C up to the moment of launch. Many special cables had to be laid from the launcher to new test racks and television monitors in the equipment centre. In Test Shop 2, a dust free, air-conditioned room was to be built to permit work on the capsule apparatus. Work at the Range was quickly under way, directed by Bruce Pitt of Missile Projects Group and Jack Redpath of Saunders-Roe.

The INS program did not cease abruptly with Blue Streak's cancellation, for it had wider applications. But its costs were soaring as difficult problems with the capsule design appeared, such as weaknesses in the glass windows under extreme heat and pressure. Work slowed and finally stopped at the end of 1960. This time ELDO brought no reprieve, but the concrete plinths at Area 5 remained for years as a monument. The next time Smith arrived at Woomera with BK13 in the following year, he heard them unkindly referred to by his friend Bruce Pitt as 'Smith's Folly.'



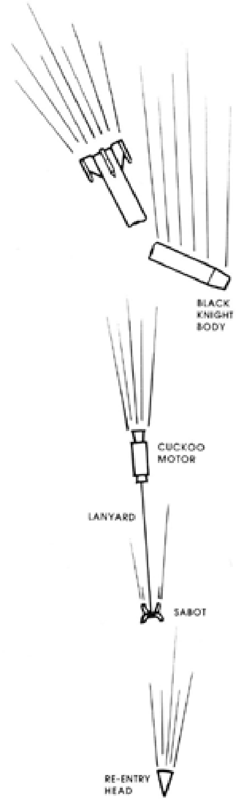
The second stage of BK16, showing the sabot.

INTO PROJECT DAZZLE

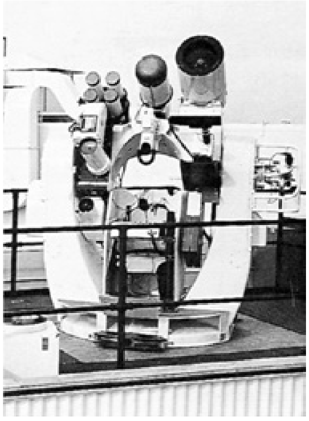
In November 1960 a quadripartite meeting was held at Farnborough between representatives of Australia, USA, UK and Canada to discuss and outline proposals for the continuing re-entry physics program which matured as Project Dazzle. At the meeting it was agreed that over the next two or three years better instrumentation would be provided at Woomera, including a special radar system being developed in California by the Stanford Research Institute (SRI: then part of Stanford University), to analyse the re-entry wakes, or trails of ionised gas behind the heads. The optical equipment already in place for Gaslight would be upgraded and the improved equipment sent for the new Gaslight trials of 1962.

BK15 was scheduled for firing on Anzac Day 1962, but in response to urgings from RAE, apparently blind to the significance of 'the one day of the year', a telex message went back: 'attempting a launch on that day [25 April] is tantamount to sacrilege'. BK15 was single stage and the payload consisted simply of a 91 centimetre diameter hollow sphere of pure copper. Since its radiation characteristics were known, this gave a reference point for the ground instruments. The flight and re-entry were perfect, although the spatial separation of the sphere was less than intended. The usually reliable guidance equipment exhibited a peculiarity on this and some later occasions; the engine flame disappeared from the guidance telescope view as the rocket gained altitude. It was deduced that a vapour trail had formed behind the rocket, opaque but invisible to the eye in the darkness. There was however no problem in switching the tracking to the guidance radar.

In August came a milestone in the Black Knight program with the preparation of BK16. This was a two stage vehicle of much improved design, intended to prove that a satisfactory vehicle was now available for the forthcoming Dazzle project. The engine was the more powerful Gamma 301, and the control system was transistorised. A further innovation was a transponder in the second stage so that the FPS-16 radars could track it independently of the main body. Finally and most radically, to achieve greater separation between the descending Cuckoo motor and the head, the latter now rested in a 'sabot'—a device of bowl shape which contained a group of small thrust rockets. It was effectively a third stage. The sabot was however attached to the Cuckoo motor by a lanyard of steel and nylon, so it was snatched away from the head when the small rockets had completed the separation process; the head then continued its meteoric descent alone and uncontaminated by other materials. Surprisingly, the brand new BK16 gave an outstanding performance. Not one of the new systems failed. The head, a pure copper cone, appeared as a brilliant streak of light as it re-entered and began to melt on descending to the thicker levels of the atmosphere. The internal tape recorder, in its protective case, survived re-entry and impact and was recovered from the Range. All the re-entering objects, including the disintegrating rocket, were beautifully photographed by ground cameras. In November BK18 repeated this textbook success. It contained the same improved first stage systems, but the head this time was an ablating cone of asbestos-resin which re-entered at 17 300 kilometres per hour, the highest speed so far attained, and provided an intense wake for the optical instruments on the Range. The sabot system was not used on this occasion and neither was the C-band transponder, but a pyrotechnic flare was attached to the second stage which ignited with it and was a useful sighting aid for the ground optics.



The separation of BK16 head from sabot during descent.



A Project Dazzle optical tracking mount, controlled by an operator on the central seat, and fitted with radiometric and spectrographic instruments.

Michael Gorroick.

Percy Hawkins.

Black Knight stood idle in 1963 while everyone waited for the advanced Dazzle instruments to arrive. The SRI radar was supposed to be delivered in October, but did not turn up until nine months later. However, the Dazzle project was at least ratified by a quadripartite agreement signed in Washington that August. (The fourth collaborating nation, Canada, contracted to do supporting research at a hypersonic ground range in Quebec.)

Except for the SRI radar all the Dazzle instrumentation was ready by March 1964 when BK12 was launched. This was essentially a test for the optical instruments, and the head was seeded to enhance the visible wake. In addition, some new rocket systems were tested: the Cuckoo motor was an advanced lightweight type and the guidance system was using its automatic operator for the first time to replace the human pilots. The flight was good but an abnormal dispersion of the second stage, coupled with a failure in the WRE acquisition system, caused many of the ground instruments to lose track. Only the ROTIM camera at Central Bore recorded the head re-entry. This unique camera supplemented the ballistic camera systems. Fixed in elevation, it rotated slowly in azimuth while its film holder was nudged forward at intervals by a predetermined time code. Even the ROTIM had captured only a faint, brief and ambiguous record, and WRE's Michael Gorroick spent many months trying to compute the point of impact. It was vital to retrieve the tape capsule with its information about the head temperature, acceleration data and so forth. After six months' work the determined Gorroick felt sure he knew where the capsule was—many kilometres away from the planned impact point. Soon after he had briefed the recovery team a call came through from higher authority to say that the search was utterly futile and must be called off at once. But too late; the team had already left, and the head was recovered hours later, buried several metres below ground. Part of the capsule is now on display in the London Science Museum.

Fortunately this difficult BK12 recovery was exceptional. Usually the recovery team prided themselves on finding the components within hours or days. Led by the intrepid Percy Hawkins they would position their vehicles at the very centre of the impact zone, confident that this was the ideal and safest point of observation. Once this theory let them down and a capsule crashed to earth only a few metres away. Hawkins, an ex-officer of the Royal Navy with a well-bred Oxford accent and matching sangfroid, permitted himself only to observe 'A close shave there, by God!' before vanishing back into his tent.

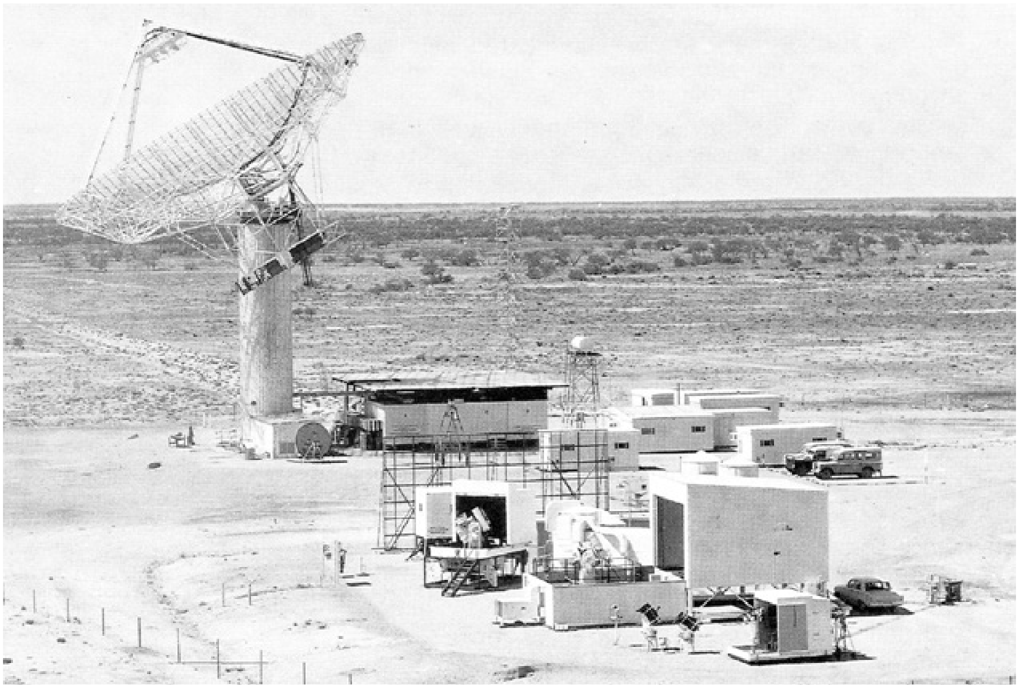
At last, by the following Australian winter, the radar was installed and operating at Central Bore, a site near Mt Eba. In order to measure the re-entry phenomena it worked on two relatively low transmission frequencies, and also the radar beam had to be very narrow to discriminate between the various descending objects. Together these two factors meant a very large aerial, consisting of a reflector dish 26 metres in diameter, mounted at the top of a 15 metre high steel tube and driven by a modified gun mounting. During tracking the great dish had to rotate downwards quite speedily. Had it failed to stop at the bottom limit of travel the result would have been catastrophic, and the operators who sat in a trailer at the base of the tower felt most vulnerable as the 20 tonnes of aerial thundered downwards. Fortunately not once did the powerful gun mount control fail to apply the brakes.

In one respect it did not quite match the requirements. The intention was that the radar should track the descending objects automatically and hand on pointing directions to the Range optical apparatus, but an aerial design fault prevented the tracking from being done automatically. WRE therefore employed an alternative system using their FPS-16 radars[36], which tracked C-band transponders in the Black Knight second stage and later in the heads themselves.

All was ready at last for the full Dazzle program of six firings, all of them two stage, or strictly three stage, vehicles. BK19 and BK20 flew before the year ended, taking aloft a pure copper sphere and an asbestos-resin ablating cone. Both rockets performed excellently; they rose to 610 kilometres and the heads re-entered at over 17 500 kilometres per hour. The only problem was with BK20, when the head did not separate cleanly and the lanyard broke soon after the sabot was snatched away. The SRI radar probed the re-entry wake of the copper head very effectively, but was less successful with that of BK20.

The last four Dazzle firings were completed in 1965, beginning with BK21 in April and followed by BK23, 24 and 25 at two-monthly intervals. Each was a separate experiment with each head varying in material and shape to provide a range of data on radiation and wakes. The four heads were a copper cone; two cones of Teflon and fused silica which are ablative materials with different erosion rates; and lastly a copper sphere similar to that used on

BK19 but more lightly built to increase the re-entry speed. All four heads were manufactured in Britain in government establishments, the fragile glass-like silica being exceptionally difficult to shape and construct. The Black Knight first stage performed very well in all four trials. One test-firing of the engine was sufficient in each case, and the only delays were due to unsuitable weather. The powered part of the flights were generally perfect, except that a turbine fault in BK23 cut propulsion three seconds early and reduced the height of the trajectory. There were some irregularities in upper stage separations. On BK21 the sabot cable broke again, but this was quickly cured for the later firings by using a different type of nylon. In each firing the head re-entered the atmosphere at about 17 900 kilometres per hour and was invariably recovered, always battered and sometimes in pieces. Great quantities of data were gathered from all the trials, but certainly the most spectacular displays were given by the silica head, which created a shower of bright fragments in its trail visible over a broad expanse of the outback.



The SRI radar at Central Bore, with the Dazzle optical site in the foreground.

THE LAST OF BLACK KNIGHT: CRUSADE

Dazzle stretched the performance of Black Knight to the utmost to attain the high re-entry speeds and payload capabilities which the program demanded. As early as 1964 thoughts had turned to designing a new enlarged Black Knight to meet further needs after BK25. Plans for the new rocket showed a shorter stubbier shape compared with the old, with its diameter increased by half. The extra volume of propellant and a more powerful second stage would give a much higher performance, which could be employed in various combinations of heavier payloads and greater re-entry speeds. At first it was called simply the '54 inch vehicle', but this clumsy title was soon changed to Crusade. But Crusade came to nothing. In September 1964 it was cancelled, superseded by the Black Arrow satellite launcher which was still based on Black Knight technology. The Dazzle program continued as described, eventually giving way to a different re-entry physics project called Sparta; but for Black Knight the end came with the launch of BK25 on 25 November 1965. For the trials teams the regrets were more than balanced by the prospect of a new and even more glamorous challenge. Even as the messages of thanks came in for those who had taken part in the firings over ten successful years faces were turning to the future. WRE Director Don Woods replied to one such message with 'we hope we shall be permitted to attempt an even greater success rate with Black Arrow'.[37]

Notes and Sources

1. ‘Planning specification for Black Knight Trials. Para. 2.3: Object of Trials’. Specification WRE 157, January 1957.
2. From a speech by R. W. Boswell at a social function in the early 1960s. Reminiscence of J. H. Redpath in April 1984.
3. H. G. R. Robinson, ‘The ballistic test vehicle, Black Knight’ (Technical Note GW 503). Farnborough: Royal Aircraft Establishment, December 1958.
4. Robinson, para. 2.3: Liquid Propellent Designs.
5. J. H. Redpath recalls this riposte came during the discussion following a meeting at Cowes about 1958. Brennan was exaggerating: the RAE input into Black Knight was great, especially over questions of propulsion, aerodynamics and control systems.
6. Reminiscence of J. H. Redpath in April 1984.
7. Papers by Senior Officer Project Planning MP Group dated 30 June 1955, 1 August 1955 and 4 October 1955. File F5411/4/1 part 1.
8. Submission to R&D Board of Management Meeting 70 of 5 January 1956.
9. Minute 1800 of the R&D Board of Management Meeting 72 of 6 March 1956.
10. The formal title of the Erroll Agreement is ‘Memorandum of arrangements covering the sharing of functions and costs between the United Kingdom and Australian governments (May 1956)’.
11. Telexes dated 27 March, 24 April and 1 June from Principal Officer Missile Projects Group to Ballistic Missiles Division RAE. File F5411/4/1 part 1.
12. Drawing T429 dated 8 May 1956. Attachment to Minutes of R&D Board of Management Meeting 75 of 10 July 1956.
13. Cost submission paper to R&D Board of Management Meeting 75 of 10 July 1956.
14. As documented in the WRE Progress Report for June-December 1956.
15. Telex dated 20 December 1957 from Superintendent Systems Assessment Division to J. D. Heinrich, Australian Representative in GW(A)UK. File F5411/1/1.
16. Black Knight Facilities: Instrumentation Plan. Planning Specification WRE 162(f) Part VI dated October 1958.
17. ‘A Handbook of Instrumentation at the Woomera Range’. Weapons Research Establishment, April 1962.
18. J. A. B. Cartmel, ‘Zulu Squire, a low acceleration sighter rocket’ (Technical Memorandum SAD 90). Weapons Research Establishment, March 1958. Zulu Squire had a cluster of solid fuel booster motors attached to it, but its own sustainer engine (derived from the RTV1 design) used LOX/methanol propellants. On its side was painted a caricature of the red-headed Higgs, despite objections that a red headed Zulu was unlikely.
19. Appendix No. 5 to ‘Black Knight Trials Instruction W1‘.
20. Contribution dated 12 December 1983 from R. N. Reeds.
21. Unpublished UK MOD data.
22. Minutes of the Black Knight WI Panel Meetings held in Australia on 21 February, 3 April, 9 June and 1 July 1958. Files F5411/7/2 and F5411/7/4.
23. W1 Panel Meeting of 21 February 1958.
24. Letter from supplier in Northants, UK to K. M. Burtt, De Havilland Team Leader for BK0I.
25. Unpublished UK MOD data.
26. Warrant Officer Couzens, ‘Report on Black Knight Firing, Operator Skyscreen (Sierra 2)’, 7 September 1958. Quoted from a copy held by K. Smith.
27. Editorial in the *Age*, 9 September 1958. Copy in file SAS 9/3/2.
28. Robinson, see notes 3 and 4.
29. Preliminary Information Paper. Systems Assessment Division WRE, 27 September 1960. In file SA5411/23/1.
30. Telex dated 18 September 1959 from Deputy Controller Trials H. A. Wills to Head of Guidance Division (RAE) A. W. Lines. File F5411/15/1.
31. P. Crosby, ‘Project Gaslight in Australia’, WRE Technical Note PAD 77 (November 1963). DRCS Library ref. SWM 31423U.

32. Crosby.
33. Crosby.
34. Woomera, thinly disguised as 'Luna City', appears in A.C. Clarke's *Prelude to Space* (1953) and Charles Chilton's *journey into Space* (1954). A radio serial, *Orbiter* X, made by the BBC in 1960-61 was set there too.
35. W. M. Jarvis and K. Smith, 'Planning proposals for flight trials of an inertial navigation system in Black Knight' (Draft Note). Royal Aircraft Establishment, January 1959.
36. WRE Report PAD 16, Part 5 (April 1967).
37. Telex dated 6 December 1965 from WRE Director M. W. Woods to Head of Space Department RAE. File F5411/1/1.

22 ‘Woomera was made for the weapon!’: *The Rise and Fall of Blue Streak*

BAD NEWS FOR PARLIAMENT

Harold Watkinson, UK Defence Minister who announced the scrapping of Blue Streak. (Hulton)

In the House of Commons on Wednesday 13 April 1960 the faces of the Members were grim set as the Minister of Defence, Harold Watkinson, rose to his feet and made a disagreeable announcement. Blue Streak, Britain’s new independent nuclear deterrent, of which the prototype was even then in San Francisco en route to Woomera for its first trial, was to be scrapped at once. On both sides of the House this news was received with glum resignation, for all were aware that the government’s decision to cancel this weapon had been a painful one which it had taken only with the greatest reluctance. Even so, it was exceedingly embarrassing, and for no one more than Duncan Sandys, the former Minister of Defence who had long championed the notion that the most efficient and economical means of defence was a system of ballistic missiles armed with atomic warheads. At home, the resulting unemployment at the factories of the contractors, De Havilland and Rolls-Royce, could not be ignored. Abroad, Britain’s reputation would suffer. The Australians, joint partners in the enterprise, had themselves spent large sums on elaborate facilities at Woomera and would be shocked and disconcerted at the news. To the Soviet strategists the decision could only signal military weakness. Over the past few years Britain had pursued the Sandys doctrine that conventional airborne arms could largely be replaced by nuclear weapons delivered by aircraft or missile, now that each such weapon could do the damage of a thousand laden bombers. The Royal Navy had been cut to the bone, an end to conscription announced, and the development stopped of a new generation of supersonic fighters and the AVRO 730 supersonic bomber. Instead the country had put its trust in the sleekly futuristic Valiants, Victors and Vulcans, a V-force of about 150 jets flying near the speed of sound and delivering their single nuclear blow from 50 000 feet. From a Valiant was dropped an atom bomb at Maralinga on 1 October 1956 and the first thermonuclear device over Malden Island in the Pacific seven months later, underscoring the terrible purpose behind the V-force. But time had caught up with the V-bombers in the seven years which elapsed between the first production order and the first operational squadron of 1956. By 1960 it was feared that they might be vulnerable at altitude to the latest generation of Soviet surface-to-air missiles. Admittedly, Britain still had the air-delivered Blue Steel, sent on its way from a bomber standing off from the target 130 kilometres or more; but that was a distance the Russian missiles would easily be able to span by the mid-1960s. America had offered a ‘super Blue Steel’, but this, the airborne Skybolt, had a clouded future. For one thing it did not yet exist. As George Brown, the Opposition spokesman on defence, pointed out, its earliest possible deployment date was several years away. And then there were technical problems. Its range might well be ten times Blue Steel’s, but probably its complex guidance system would be vulnerable to even a distant nuclear burst. Finally, adopting Skybolt meant abandoning the dream of an entirely independent nuclear deterrent delivered by missile. In fact Skybolt’s day never came. Polaris rendered it obsolete and the Kennedy administration cancelled it in 1962.

Yet the reality had to be faced—to continue with Blue Streak was politically impossible. It had already cost the taxpayer more than a hundred million pounds, of which twenty million alone had been spent on building from scratch a static test facility on bleak moorland near Carlisle. Yet the spending which thus far had produced nothing of military advantage had hardly begun. The Chancellor, Heathcoat Amory, had been alarmed to receive the advice that to complete the project could easily cost another £500 million, a startling sum in those days.[1] On top of Britain's other defence commitments such a sum could not be found without visible effect on the country's standard of living, and the British were tired of austerity. They had had enough of guns; they wanted some butter and they had elected the Macmillan government in 1959 mainly because it had promised a consumer boom. And then, even if Blue Streak were completed, there was now no guarantee that it would fulfil its purpose. It too had fallen prey to technical obsolescence. Since its design had been fixed several years before, both superpowers had greatly improved their guidance techniques. As recently as January of that year the Russians had boasted of firing a missile 12 000 kilometres over their mainland and into the Pacific with pinpoint accuracy. With a nuclear warhead against a point target, increased accuracy is more significant than increased yield: a doubling in accuracy has, roughly speaking, the same effect as an eightfold increase in explosive power. No fixed launcher installations were now secure from a pre-emptive strike. The sixty American liquid fuelled Thors sitting on their platforms in eastern England under a 'two key' agreement had become obsolete and would be phased out over the next three years.

Even the planned underground silos for Blue Streak, a later addition to the system, were now vulnerable. Just before the cancellation was made public, the Ballistic Missiles Early Warning System had been approved for construction, but even when it was finished the Fylingdales station on the Yorkshire moors would only offer the proverbial 'four minute warning' of missiles coming in on low trajectories over the Pole. Four minutes was not long enough for Blue Streak to be fired if all its silos could be destroyed at a first strike. None of this was news to the Americans, who as early as 1956 had come to the conclusion that no liquid fuelled missile, not even one launched from the US mainland, could be given an adequate response time. So, while Blue Streak's development was forging ahead, they had launched a great research effort in another direction entirely: to perfect a solid fuel motor using new propellants of sufficient power to give a 10 000 kilometre range. Between 1958 and 1961 they developed Minuteman: cheap (one-fifth of the cost of the big liquid propellant ICBMs), easy to keep on standby and with a response time of less than a minute—hence its name. Almost simultaneously they produced a long-term solution to the problem which doomed Blue Streak. This was the Polaris system, using missiles launched from submarines wandering in the depths of the oceans. The first Polaris nuclear submarine, the USS *George Washington*, went on patrol in the summer of 1960. Polaris could get away sixteen nuclear-tipped missiles in fifteen minutes from a virtually unlocatable launcher, but developing such a complex system had been phenomenally expensive. It was raising the bidding to a point where Britain simply could not afford to retain a fully independent hand.

It was understandable that in the first moments of chagrin accusations of waste and mismanagement should fly freely. The Conservatives were cruelly lambasted by the Opposition, not least by Harold Wilson, then Chairman of the Public Accounts Committee, who asserted that Blue Streak had been kept going purely to save Sandys's face. 'We are looking', he said in a much quoted quip, 'at the most expensive face in history. Helen of Troy's face may only have launched a thousand ships, but at least they were all operational!' The Macmillan government had to face a censure motion which deplored 'the expenditure of a large amount of public money on a project long believed and now officially declared to be of no military value'. To the criticism that Blue Streak had been persisted with long after its failings had become obvious Minister Watkinson had no effective answer. But, as he hastened to say in the ensuing debate, back in 1954 Blue Streak had been a logical enough conception. The cold war was then at its most arctic. Hardly anyone in the West doubted that international communism was on the move when over the preceding few years Berlin had been blockaded, Czechoslovakia had become a satellite of the Soviet Union, China had fallen to Mao's People's Liberation Army, and the Communists had invaded South Korea. We should recall that the United States did not at that date have ICBMs able to penetrate deep into the Soviet Union from its own territory. It did acquire them soon after—as British strategists rightly predicted—so in 1954 the fear was that the US might eventually find it convenient to withdraw from Europe, leaving the allies to shelter under her nuclear umbrella. To many Britons this was a humiliating prospect. They had not yet grown used to the idea that their country was no longer the head of a global empire: Suez, the turning point

Harold Macmillan.

in the process of disillusionment, was a couple of years in the future. The missile- delivered nuclear deterrent was a way of colouring up Britain's fading image as a world power of the first rank. Macmillan himself, with his frequent talk of a 'second Elizabethan age' appealed directly to this chauvinistic motive:

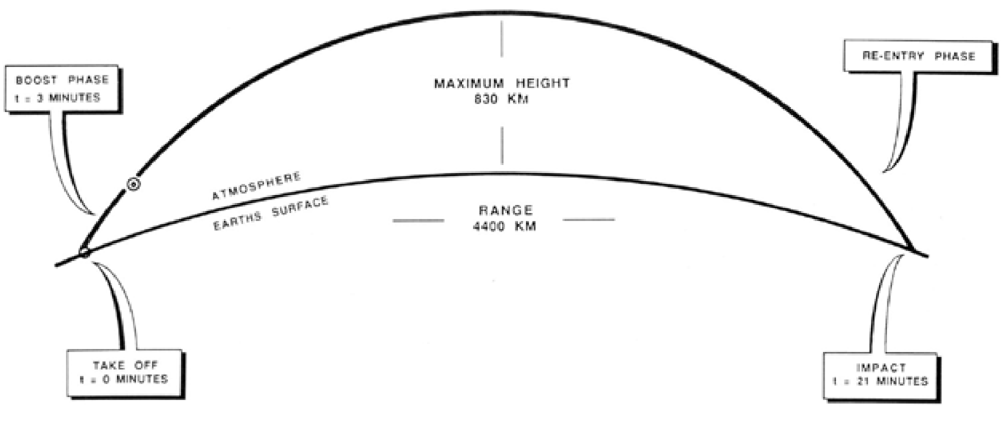
> The independent contribution . . . gives us a better position in the world, it gives us a better position with respect to the United States. It puts us where we ought to be, in the position of a Great Power. The fact that we have it makes the United States pay a greater regard to our point of view, and that is of great importance.[2]

As this quotation hints, Blue Streak was not only a physical weapon against an aggressor but a rather blunt instrument of diplomacy against America. Insecurities about America's intentions, with their source in jealousies over the changed post-war status of the two countries, were running deep at this time. Many conservative Britons found attractive the idea of being able to retaliate in kind if they became subject to nuclear aggression, without having to seek permission from an ally. Another strand in such strategists' thinking was that having their own nuclear force was a good way of obliging the United States to be their protector even if its own survival was not directly threatened, because America could not afford not to defend a country that had the power to involve it in a central war.[3]

THE DESIGN AND DEPLOYMENT OF BLUE STREAK

And so in 1955 the contracts for the new missile had been let: to De Havilland Propellers (later part of Hawker Siddeley Dynamics) for the general design and airframe; to Rolls-Royce for the engines; to Sperry Gyroscope for the inertial navigation system; to Marconi for the ground radar and communications links. The thermonuclear warhead was developed at the Atomic Weapons Research Establishment at Aldermaston, and was tested live by being dropped from a Valiant bomber at Christmas Island in mid-1957, under the code-name Orange Herald.

As the whole weapons system took shape under the hands of the De Havilland engineers, it was a program for Armageddon. Behind it stood the newly conceived MAD doctrine: Mutually Assured Destruction. As Winston Churchill put it in his famous epigram about this time, henceforward safety was to be 'the sturdy child of terror, and survival the twin brother of annihilation'. Any aggressor would take pause (so the reasoning went) by the certain knowledge that even if he struck without warning some Blue Streaks and their crews would survive unscathed in their silos deep underground. Even if the landscape was desolated and most of the population dead, the great portals protecting the missile shafts would still yawn open, their great bulk and powerful water jets sweeping aside the shattered ruins on the surface. Each cover weighed 750 tonnes and was strong enough to withstand the steel-melting heat of a nuclear fireball nearby. Just seventeen seconds later Blue Streak—3 metres across and 21 metres long—would emerge on its 20-minute journey of vengeance, arching high out of the atmosphere on its ballistic trajectory. Its engines would be alight for less than four minutes, during which time its inertial navigator would constantly compare its position and velocity with the required values in its data store and make adjustments to suit. After burn-out the re-entry head would separate high in space and soar on, leaving the rocket body to be slowed by its retrorockets and to burn up like a meteor in the atmosphere. The head had its own small vernier motors, and one of the last instructions of the guidance system would

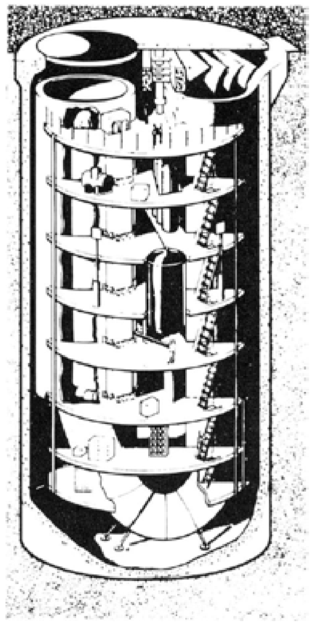


The intended 'journey of vengeance' of Blue Streak.

be to tell it how many of these oddly named 'bonkers' to fire to give a precise final velocity. Later other small squibs would fire to tilt the head to the correct angle of re-entry and to spin it for stability. Protected by its heat shield (tested on Black Knight) the glowing warhead would plummet down through the thickening air to explode high over the target.

In order to bring the whole of the western USSR into range of Blue Streak, the operational requirements called for many underground silos in the British countryside and in the Middle East. Finding sites for the silos on British soil was the responsibility of the Home Office. It was not an easy task. For strategic reasons the sites had to be widely dispersed, and to be blast-proof the silos had to be sunk deep into granite. There are few places in eastern England where the strata are the requisite 100 metres or more thick. The best sites geologically were in the more mountainous and rocky western parts of the British Isles, and these had the disadvantage of being further away from the target.

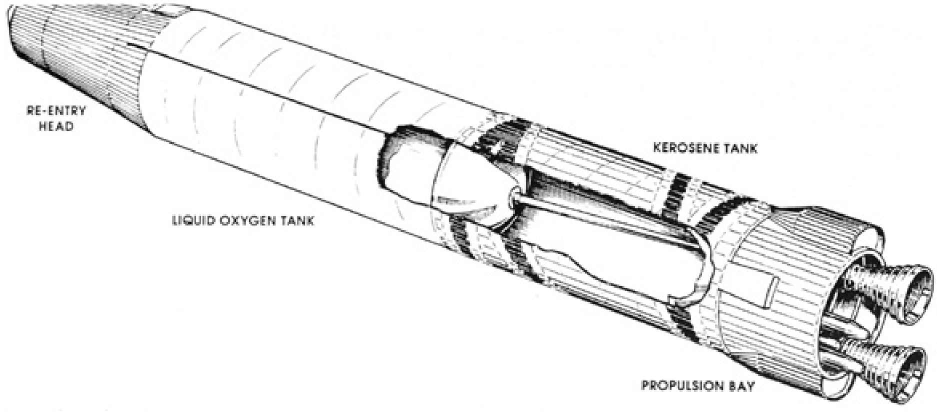
By January 1960 one silo, to serve first as a proving ground but later to be handed over to the RAF as an operational site, was on the verge of being built under the code-name K.11. Originally intended to be near the US Thor installations at Duxford in Cambridgeshire, K.11 was in fact planned for Upavon in Wiltshire because of groundwater problems at Duxford. Some borings were made at Upavon to test the stability of the subsoil, but if the actual construction began it could not have proceeded far before the cancellation. Had it ever become operational, K.11 and its counterparts elsewhere would have consisted of six levels sunk 46 metres alongside the launcher shaft, occupied by a crew on duty round the clock. These troglodytes would have been independent of the surface, with their own food, water, air and power. The launcher shaft proper was a U-tube, in which the missile would have been suspended part-way down one arm on four concrete shock-proof bearers able to take 80 tonnes each. Lining the tube were acoustic panels to absorb some of the intense noise and at the base of the U-tube was an exhaust deflector of Ciment Fondu and crushed firebrick, to absorb the heat of the exhaust gases and to guide them up the other arm and through blast traps into the open. These fittings would be ruined in the firing but it was not important: this bee had only one sting.



K.11, the proposed underground silo at Upavon.

The thermonuclear warheads then possessed by Britain were heavy, weighing about 2 tonnes, and to carry one by rocket several thousand kilometres into the heartland of the USSR automatically meant using liquid oxygen (LOX) as one of the propellants. This posed the problem that the LOX could not be kept on board; if it had been, the whole rocket would have frozen up after a few hours. Yet Blue Streak had to be in readiness night and day with its kerosene fuel loaded, the warhead in place, the target co-ordinates set. Then, if the command to fire ever came, all that remained to do was to load the LOX and run up and stabilise the gyros. With some improvements, De Havilland considered the whole process might be reduced to 5 minutes.[4] A remarkable system was devised to load the LOX at very short notice. The plan called for 120 tonnes of it to be stored in the silo in a shock-proof vacuum tank. (It slowly boiled off, of course, but the tank was replenished by reliquefying the escaping gas—the most economical method.) Pumping it on board was not feasible, partly because pumps would be too slow in those vital last minutes and partly because the big diesel generators powering the pumps might not be dependable in a crisis. Instead, the 65 tonnes of LOX would be literally blown on board in the last 3½ minutes, using the force of 6 tonnes of compressed nitrogen kept permanently stored in cylinders. Since the missile already had 27 tonnes of kerosene on board in a thin-walled tank, the safety problems needed some close attention. These were to be resolved at Woomera, by building two silos with most of the features of K.11 except for the blast and radiation protection.

Blue Streak was a 'British' missile only in a rather limited sense. Its design was heavily indebted to a licence agreement which allowed its engineers to draw on current American techniques, especially those employed in General Dynamics's, Atlas, the first true ICBM. The airframe was little more than two thin tanks of liquid forming a metal-skinned tubular balloon. The tanks—in reality one tank divided by a diaphragm—were formed of circles of stainless steel sheet, seam-welded together into a cylinder, and their walls were no more than half a millimetre thick. Blue Streak was so fragile that it had to be kept pumped up hard with nitrogen from the time of manufacture, throughout the long shipment from Britain and right up to the moment of launch at Woomera, to prevent its collapsing under its own weight. (During shipment the tanks were stretched in a handling frame to give some insurance against pressurisation failure.) Although the rigidity and toughness of the airframe relied on exactly the same principle as a pneumatic tyre, in the early days of the Atlas development



Most of the space of Blue Streak was occupied by the large thin-walled kerosene and liquid oxygen tanks. The two engines in the rear propulsion bay had gimbaled chambers to steer the missile while burning.

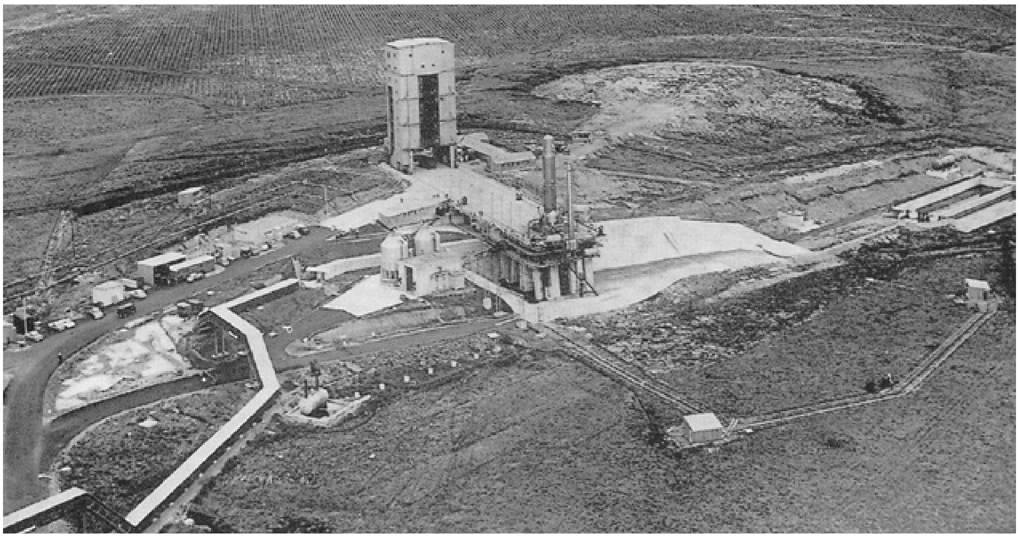
some engineers suspected that the hide of the rocket might be accidentally punctured too easily. The Atlas historian, John Chapman, has an amusing description of how an exhibit was set up to quell the sceptics:

> Finally, after witnessing much wringing of hands over the probable hazards of dropped tools, accidental kicks etc., Convair engineers built a box about two feet square and covered one face of it with one of the thinner gauges of stainless steel. They pressurised the box, set it up in the Atlas project office alongside a hammer and a screwdriver, and waited for the pessimists. Invited to swing a hammer at the steel surface, a doubter would usually respond with a light tap. 'Lay into it', he would be told. And when he laid into it, and felt the hammer bounce harmlessly off the thin skin, he would begin to get the point.[5]

The concept was sound enough yet the tolerances were fine, allowing little room for mishaps. For instance, all that separated the contents of the LOX and kerosene tanks was a thin metal membrane, and during one of the early tests it ruptured, allowing the contents to mix. The result could well have been a catastrophic explosion. Very fortunately, however, because little was known at the time about moving large quantities of liquefied gases, chemically inert liquid nitrogen was being used in this early testing of the pumps, not LOX. This gives some idea of the cautious approach the engineers used, and of the potential dangers.

Below the tanks were two Rolls-Royce RZ.2 engines. These were based on a Rocketdyne design, but the British engineers had improved their performance and efficiency to the point where they were virtually new machines. Although they ran on cheap kerosene fuel, they were extraordinarily powerful: for a weight of only 680 kilograms, they produced a thrust of some 60 tonnes. The propellants were fed to the combustion chambers by powerful turbopumps, driven by a gas turbine also burning kerosene in LOX. Inside the chambers the temperature exceeded 3000 degrees centigrade, yet the walls remained relatively cool at about 400°C. This was achieved by making each chamber out of an assembly of 312 thin-walled nickel tubes, through which the oxidant passed up and down on its way to burning. The chambers were protected against bursting by being ringed on the outside with broad steel bands. To control the attitude and direction of the rocket, both thrust chambers were gimbaled, permitting each one a movement of some 7 degrees in any direction. The propellant pipes from the pumps had therefore to be partly flexible. The engineering difficulties can well be imagined, especially when the liquids are under high pressure and one of them is 183°C below freezing.

The thirty thousand or more distinct parts of the complete rocket—a veritable maze of electronics, pumps and tubing—were assembled at De Havilland's plant at Stevenage, north of London. At the remote Spadeadam Waste in Cumbria, next to an old farm known for generations as 'Moscow', the Ministry of Supply built the most advanced testing facility in Europe, the sprawling Rocket Establishment. Here the bellowing of engines on test mingled incongruously with the bleating of sheep grazing on the desolate fells. Spadeadam contained four engine stands and two stands capable of taking the entire rocket for static tests. Each missile stand, weighing hundreds of tonnes, rested on four multi-wheel bogies. After the missile had been brought to the stand by transporter, it was raised vertically by winches and the complete assembly moved to the end of a long concrete causeway to the actual firing place. The test was controlled from a distant blockhouse connected to the stand by several



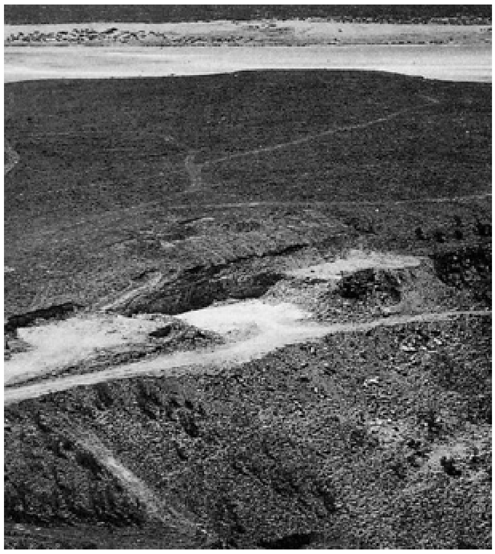
One of the test stands at Spadeadam Rocket Establishment, showing a complete Blue Streak erected for static firing.

thousand cables, and its progress monitored by periscope, TV and cine cameras. Naturally Blue Streak would never take to the air over Cumberland—at least, not in peacetime. This was the role of Woomera.

BLUE STREAK AT WOOMERA

Trials on the colossal scale required for Blue Streak went far beyond any purpose to which Woomera had yet been put, and in fact harked back to the earliest planning for the transcontinental Menace weapon contemplated and quickly dropped just after the war. Blue Streak gave WRE all the work it could handle. Elaborate facilities were needed at the launch area, similar to but more complex than those at Spadeadam. The trickiest engineering problem at the launcher area was disposing of the waste heat. In their development phase the RZ.2 engines would be run at full thrust for half a minute or more while the rocket was tethered. Providing a cooling water service over the much smaller Black Knight launcher had gobbled up a third of the total launcher costs, so this time WRE was determined to find a site that did not need water cooling. The solution was to push out two vast concrete launcher emplacements from an escarpment overlooking the saltpan of Lake Hart, 12 kilometres south-west of the rangehead, from which the exhaust flames of the missile could blast down harmlessly into the gully before being deflected outwards by ordinary refractory tiles. Then a purpose-built equipment centre had to be linked to the launchers and the rangehead by a skein of cables. At Woomera West a big plant had to be put in to generate and store liquefied gases. The full length of the Range had to be surveyed right out to the Western Australian coast, roads built and remote instrumentation posts installed. As well as a chain of ballistic camera sites, new safety tracking radar stations had to be built. One was at Red Lake, not far from the Lake Hart launcher. The other was at Mirikata on McDouall Peak station, not far beyond the original site for the rangehead at Mt Eba. From this point 170 kilometres out along the Range line the flight of the Blue Streaks would be monitored as they passed overhead.

A much bigger and even more expensive requirement was for an impact zone to be created from nothing 2000 kilometres away on the north-west coast of Western Australia, north-east of Port Hedland in the Great Sandy Desert. Given that communications from this remote spot back to Woomera had to be excellent, it is not surprising that the first cost estimates in July 1956 allowed nearly a million pounds for the telephone and data lines alone.[6] Then there were the security difficulties. Most aspects of Blue Streak were highly classified, especially its range, the length of the firing sequence and details of the nuclear warhead. The British were especially adamant that the target accuracy, both planned and achieved, must be kept very secret. Unfortunately, as Chief Scientist Butement had to point out, it is impossible to keep totally under wraps a rocket designed for firing across a continent. The instrumentation plan called for a network of ballistic cameras to photograph a flashing light on the missile while it was above the atmosphere, against a background of



Right: Blue Streak launcher 6B under construction at Lake Hart. Unlike 6A it was never used.

Far right: Early earthworks for 6C and 6D at Lake Hart.

fixed stars. A ship far out to sea could easily pick up these flashes with simple equipment, and from them compute the trajectory and probable impact point. Enforcing total secrecy at Woomera was therefore impossible although all that could be done was done, at great expense and effort.

The question naturally arises why the Menzies government accepted such an onerous task at all, even though its financial obligation was limited under the Erroll Agreement of 1956. What could that government possibly have found appealing about a nuclear-armed ballistic missile, an inflexible weapon at best, and in this case one specifically designed to have a performance and range appropriate to a European theatre of war? One answer was that the end product was not so important as the expertise which might be picked up along the way, particularly in the handling of big rocket engines burning liquid propellants. Another was that the idea of a united British Commonwealth defence was still very much alive, along with the assumption that Britain's potential enemies were Australia's too. And finally, extraordinary though it may seem, the third answer was that Australia might one day wish to arm itself with Blue Streak or its successors. This last idea was floated in March 1956, when Butement was asked to write a brief for the Minister for Supply in preparation for the Erroll visit. In the brief Butement offered some interesting personal opinions on what the introduction of the new deterrent weapons would mean for the British Commonwealth as a whole and Australia in particular.[7]

Whatever may have been the exact mix of reasons for the government's enthusiasm for Blue Streak, it set to work with a will. Inevitably the cost was enormously high. In the single financial year 1959-60 joint project work in Australia cost the partners over two hundred million dollars in present values, and nearly all of it went on Blue Streak. The effort required was on a par with that of founding Woomera in the first place. As the work gathered momentum the Minister for Supply, Alan Hulme, wrote to a colleague impressing on him the need to meet the British deadlines regardless of the cost. It would, he said, 'necessitate some short cuts and unorthodox procedures', some of which might well be open to criticism; and he went on to outline a few possibilities. They were justified, he thought, because 'the plain fact of the matter is what we are about to do is vital to the United Kingdom Government, and indeed to the free world', and if this meant partly abandoning the usual checks on costs, then so be it.[8]

Even with this free hand WRE found its biggest headache was signing on enough new staff. Six teams of radio technicians were put on a guaranteed 20 hours of overtime a week, but it was nothing like enough. The country was scoured for scientific and experimental officers, and the retirement lists were combed for people who might be lured back to work. Despite repeated radio advertising campaigns the harvest was thin, for the work was both demanding and specialised. In Brisbane advertisements for optical technicians brought many inquiries from optometrists, but when they saw the intimidating list of duties very few could be tempted away from spectacle making. Evidently, as Boswell said, the professional depths had been plumbed; and so the recruiters went further afield: to New Zealand for mathematicians and to Canada for electronics engineers.

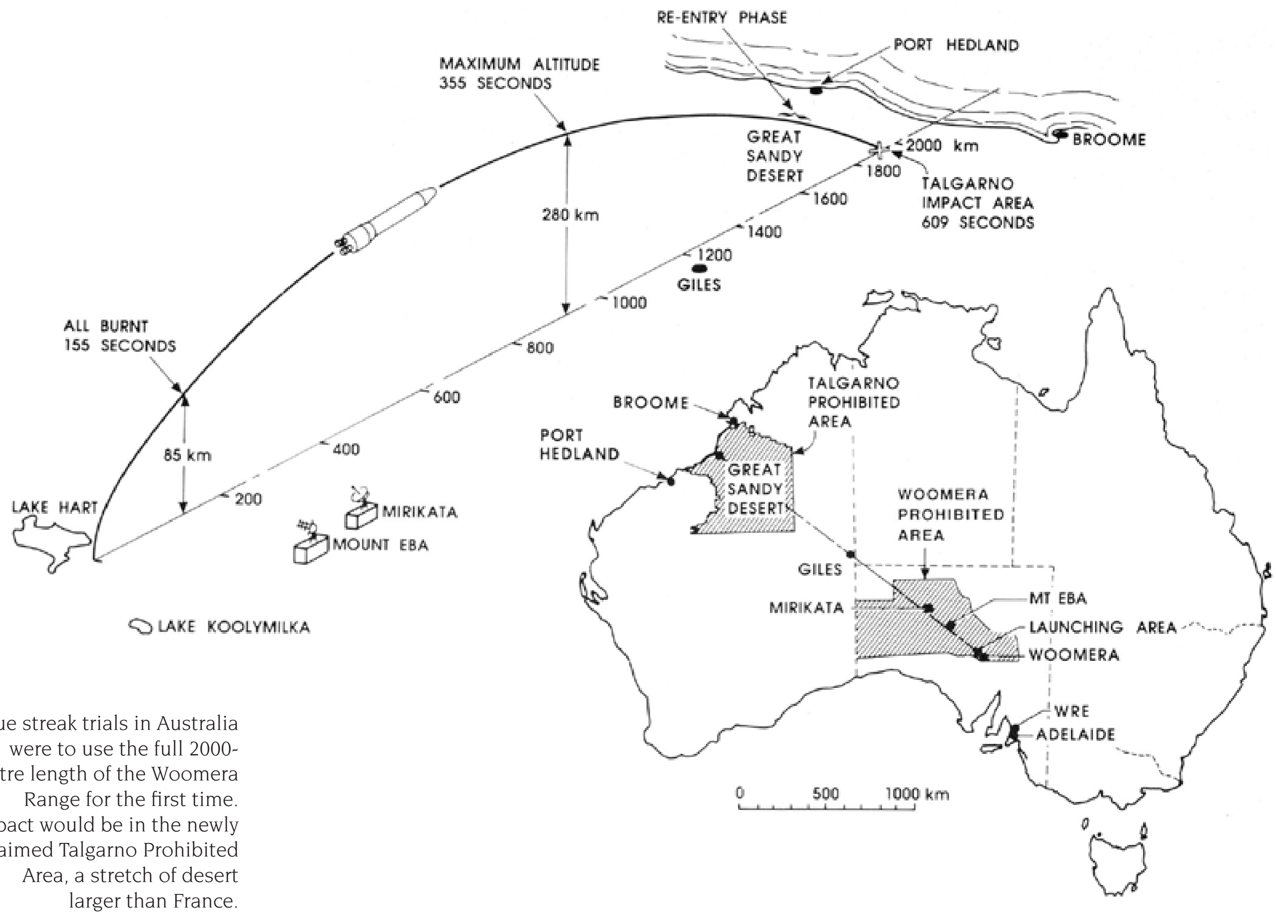
By the time of the cancellation these heroic measures had certainly worked. Almost everything was poised ready for the start of a program which, according to the planning specification, was to see a steady stream of Blue Streaks arriving by sea and making a fiery departure at the rate of one a month or more for the next few years. On the rocky and arid terrain around the northern edge of Lake Hart had arisen a partial duplicate of Spadeadam. One of the gargantuan ferroconcrete launchers (6A) was practically complete, and the other (6B) was a few months behind it. Each had a servicing tower, 500 tonnes in weight and eight storeys high, running on rails along a causeway out to the apron jutting over the edge of a gully 40 metres below. Below the emplacement a broad-angled duct served to deflect the exhaust gases out over the lake bed. Built into and around each emplacement was a mass of equipment: fire-fighting gear, storage and filling systems for fuel and oxidant, a tall umbilical mast and all the communications, control and monitoring networks. Poised there on the edge of the gleaming saltpan they made an impressive and futuristic sight. To those who had been at Woomera from the beginning, no doubt it seemed that the Range was at last achieving its destiny. This was what it had been planned for, after all; to hurl rockets half-way across a continent, not to test short range guided missiles or to conduct unexciting bombing trials which could be done in a dozen places.

The launchers were only a small, if the most dramatic, part of the effort Australia had put in over Blue Streak. Elsewhere on the lakeside, circular earthworks marked the sites where two sunken launchers (6C and 6D) were being excavated. At present they were just holes in the ground. Within two years, though, they would be working but simplified versions of the operational silos in Britain, without any radiation proofing and with their LOX storage and transfer system on the surface. To save costs they took the form of concrete tubes built into the side of one of the ravines on the lake shore, although tentative plans allowed for a 6E launcher which apparently would have been a complete and functioning subterranean silo. A short distance inland from the lake stood the equipment centre, most of its instruments in place ready to record the first lift-off now a bare two months away. Back at the rangehead the Instrumentation Building had been almost doubled in size with an extension wing stretching down one side to house the new telemetry, computers, plotting boards, communications etc. Over the hottest summer months of 1959-60, without air-conditioning, technicians of the PMG and WRE had given up their leave and worked long overtime hours to get it finished so that regular trials work could continue after the stand-down period. At Red Lake, and far out along the centre line at Mirikata, stood fresh new buildings fitted with the advanced American FPS-16 radar.

FAR AWAY AT TALGARNO

Much further out still, near the Western Australian coastline, the Talgarno Prohibited Area had been proclaimed in December 1958 as the place into which the inert warheads would fall after their continent-spanning flights. Talgarno was bigger than France, and most of it was part of the Great Sandy Desert. Even this very remote area was not quite uninhabited, though the average population density was small indeed. Along the coastal strip were five station homesteads occupied by the property managers, their staff and families, amounting to about 200 people. In the north-west corner of the area, near the boundary, was the Aboriginal mission of La Grange, home to about 120 children with about the same number of adults in camps nearby. Finally, a small number of nomadic Aborigines were thought to be wandering the desert, although even the experts knew little definite about their movements. When the Minister for Supply, Athol Townley, visited the area in June 1958 he guaranteed all the residents' safety, promising them fair warning of firings and shelters for their protection. Special measures would be adopted to look after the welfare of the nomadic people.[9] These assurances were proper and timely. But it was only a few months later, after WRE's tireless Safety Officer, George Foreshew, had visited the United States Atlantic Missile Range from which large missiles were fired across the open ocean, that Salisbury could assess the real risks more dispassionately. The American practice, Foreshew discovered, was to allow a firing when the density of ocean going shipping did not exceed thirty-four vessels spread over 25 900 square kilometres of Atlantic Ocean, providing that the risk of a hit did not exceed one in 100 000. At Talgarno the risk was much smaller than that. There were only twenty-four buildings scattered over the 40 400 square kilometres of

George Foreshew, WRE's chief safety officer.

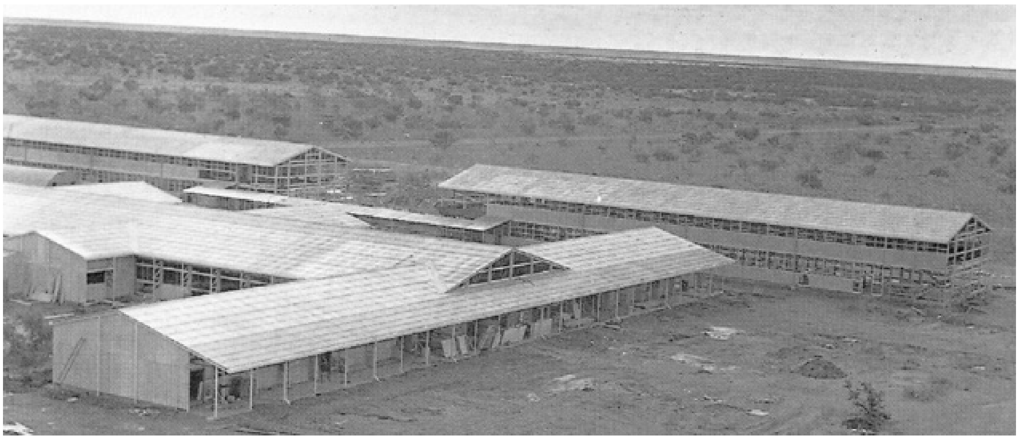


Blue streak trials in Australia were to use the full 2000-kilometre length of the Woomera Range for the first time. Impact would be in the newly proclaimed Talgarno Prohibited Area, a stretch of desert larger than France.

the coastal strip, and unlike the situation at Woomera all of them lay beyond the perimeter of the impact zone. Calculations put the probability of a hit on a building at less than one in a million, and for some buildings, including the twelve which formed La Grange mission, at only a tenth of this. So small a risk is hard to visualise, but as a point of comparison statistics showed that in the mid-1950s any South Australian stood a one in 7500 chance each year of accidentally suffering a fatal fall.[10] By the standards of everyday life, then, Blue Streaks falling into Talgarno posed a threat too tiny to worry about. So at least the stout pastoralists of the area must have concluded, for in the course of discussions in 1959 they readily agreed that shelters were unnecessary.

Talgarno was more than just a stretch of desert into which Blue Streaks could fall harmlessly. Since much of the value of the weapon lay in how closely to the target it could land its nuclear warhead at the end of its long ballistic trajectory, Talgarno was to be well instrumented to fix the point of impact to within 30 metres. It consisted of a primary impact zone 96 kilometres across with a big safety area around it. Ballistic cameras ringing the primary zone would chart the path of the incoming dummy warhead and special telemetry would record signals from the fuzes as they triggered on impact.

The working assumption was that Blue Streak would have a life stretching through the 1960s at least. In addition, further plans for Talgarno included elaborate experiments into anti-ballistic missile decoy discrimination radar (DDR). Incoming Blue Streak warheads equipped with various kinds of decoy were to be examined electronically to find out how efficiently the real warhead could be detected. Had it ever been built the DDR facility would have been a huge undertaking. A hemispherical receiving aerial made of a thousand tonnes of foamed polystyrene was only one component of the system. With these developments in prospect, Talgarno base was designed as a permanent township: a miniature Woomera with a school, hospital, pool, tennis courts, an outdoor cinema and family housing. The site was a small slice of land excised from the huge Anna Plains leaseholding. Building the construction camp, ten family houses, the airfield, the mess, the flats for 150 single staff and the sewage plant proved more than a little troublesome. The nearest construction plant was at Geraldton, 1600 kilometres to the south, and all the materials came from there



The Talgarno mess and single living quarters under construction (March 1960).

or even further afield. Eight months of the year saw a total of six rainy days on average, while in the wet season the De Grey river sometimes became a raging and impassable torrent, cutting the road between Anna Plains and Port Hedland for three months at a time. Skilled tradesmen were rare and the tropical lassitude hard to overcome. On one occasion a WRE party, including a very British visitor so proper that he was reputed to wear Harris tweeds while gardening, sought refreshment in the raffish seaport of Broome. To this man's incredulity the slatternly waitress greeted the party with a surly 'Gidday. What do youse bastards want, then?'—apparently the habitual mode of address in those parts. The physical conditions of life at Talgarno were equally rough. They were feelingly expressed in a report by the sole security officer posted there, composed just before the cancellation:

> Artesian bore water, laid on to married quarters, is unsuitable for human consumption and exudes a metallic stench which lingers on the body and clothing after drying. The climate at Talgarno in summer months (wet season) is enervating and oppressive, the flies intolerable, and the dust distracting. Temperatures have been known to rise to 114°F. There is no relief from these conditions in either tented or prefab accommodation. The local beach area is mainly silt and is subjected to disturbance by tides. Swimming is out of the question as the sea at Talgarno abounds in sharks and sea lice…[11]

Nevertheless, in this dismal place cyclone-proof housing for a thousand workers was up or planned, and it had already seen a grand opening dinner with caviar, thrown for the surrounding pastoralists by the Minister himself.

THE CANCELLATION BOMBSHELL IN AUSTRALIA

According to Harold Macmillan's memoirs the decision in principle to cancel was taken by his Cabinet Defence Committee on 24 February 1960, although the work was allowed to go on while an understanding was reached with the Americans over the supply of Skybolt.[12] In fact the future of Blue Streak had started to look insecure much earlier. As far back as 1957 contracts for the Marconi radar guidance system and the English Electric 'insurance' inertial guidance system had been cancelled to save money. In the middle of 1958 a quiet assessment had been made of the savings which would accrue if Blue Streak were not taken to the operational stage, and by the end of the year the Cabinet Defence Committee was inviting the Minister of Supply to arrange for work to be 'unobtrusively retarded' while the position was reviewed.

The Treasury's resistance to continuing Blue Streak had hardened considerably over the extra cost of putting the missiles into underground silos to make them less vulnerable. Since most of the services would be needed whether the missiles were on the surface or underground, the silos would have added only a small increment—about 6 per cent—to the total cost of the system, but they became something of a focus of Treasury concern. The actual amounts were of course substantial. At first the price of each fitted silo was put at around £3 million, not including the missile. But there were due to be seventy of them in all, and once the planning of K.11 started seriously the estimates rose sharply to £4.7 million for each one. After the Air Council endorsed underground deployment at its meeting of 30

April 1959 and asked for Treasury approval, the Chancellor, Heathcoat Amory, became even more obdurate in his resistance to continuing with the weapon, and he sparred frequently with Duncan Sandys over the issue both verbally and in correspondence.

Sandys's position was a coherent one. He argued that if the requirement for a new independent British nuclear deterrent was accepted as given, then the expenses were bound to be heavy. Any home-grown nuclear delivery system, no matter whether it used rockets launched from the ground, from the sea or from the air, was going to have a price tag of £500 million or more. The justification was that such a system would give the country a military power, security and influence greater than anything obtainable by spending a similar sum on conventional forces. A great deal had already been spent on Blue Streak, and cancellation would itself incur heavy costs. Sandys was content to have the whole question of a ground-launched deterrent examined by a study group under the chairmanship of Sir Richard Powell. In the meantime, though, he insisted that there should be no reduction of effort.

S. Hulme. Australian Minister of Supply in 1960 (PA).

John Knott

Admiral Sir Charles Lambe, RN, at Woomera with Boswell, just before the cancellation was announced.

But despite Sandys's most persuasive efforts, Amory refused in January 1960 to sanction further expenditure to the tune of some £2 million at Talgarno. He stuck to the letter of the Prime Minister's directive that expenditure should be cut as much as possible without giving anyone the impression that the project was being abandoned or retarded.[13]

Little, probably nothing, of this was known officially in Australia. Even at the highest levels within Supply, the extant correspondence suggests that no one had any inkling that by the middle of 1959 Blue Streak was fighting for its life. The only ominous sign was that as the year drew on it became increasingly obvious that MoS was dragging its feet over approvals for expenditure, especially for the construction of vital new blocks of flats at Woomera. After three months of delay, Supply Minister Hulme, who had apparently been reduced to taking his information from the British magazines, wrote on 31 July to his counterpart, Aubrey Jones, to suggest means of speeding-up approvals and to inquire whether the Blue Streak facilities were still as urgent as his Department was assuming, bearing in mind 'recent press reports which have indicated that a certain amount of pressure on the IRBM has been eased'.[14] Hulme's energetic Acting Secretary, John Knott, began to plan a visit to London for his Minister, himself and Boswell; but this fell through when what was interpreted as a rather cool response from Jones was received more than a month later saying that, as they were in the throes of the Defence Budget, it was perhaps not the most propitious time for a visit. Menzies then communicated directly with Macmillan. He spoke bluntly of the problems 'which if not smoothed out quickly will make it very difficult for us to do our part in meeting the agreed time schedule for planned firings', and suggested that a MoS official should come soon to Australia. Macmillan answered promptly in mollifying tones—'I am distressed that you should feel that the difficulties in correlating action in our two countries may cause delays'—but, reasonably enough, he wanted to put matters off until after the election due that month, at which his government was returned with a handsome majority. When he did come back to Menzies—three months had passed in the meantime; it was now January 1960—it was only with the news that Watkinson, the new Defence Minister, was engaged in a review of the whole missile program and he wanted to wait for the results of the study.[15] As late as the end of February H. P. Matthews, the Department of Supply's senior representative in London, was reassuring the executive committee on Blue Streak in Melbourne that Australia would certainly be notified before any decision affecting the joint project was taken. In fact the decision to cancel was preceded by no consultation whatsoever with Britain's partner, and anticipated Watkinson's statement to the Commons by less than a month. The news was broken to Menzies by the First Sea Lord, Admiral Sir Charles Lambe, when he visited Canberra on 16 March bearing a personal letter from Macmillan. Lambe's mission was delicate. It was during their meeting that Menzies is recorded as saying that 'Woomera was made for the weapon and not the weapon for Woomera!' but whether he delivered this shaft in tones of resignation, exasperation or fury is unknown.

WRE itself received absolutely no advance warning of the public announcement. After the news broke, Boswell arranged a symposium to assess the situation, and in his opening address said bravely:

> I would like to stress that to us Blue Streak was just another project—certainly a very big one—and, like other projects, it did have its own special purpose facilities; but again, like other projects, it gained its main support from the capital already invested in the range.[16]

This was true as far as it went; but still, the net effect was as though some great machine running at full speed had been thrown suddenly into reverse gear. Some of those special facilities, like the large rocket assembly building at Salisbury, could easily be completed and used for other things. But others could not. At Woomera, Launcher 6A was all but finished. Launcher 6B was a little behind with not all of its services connected. More work had to be done to bring it to a point where it could be moth-balled, but there was never any question of making it operational. Eventually it was scrapped, complete and still unused. The excavation for the underground silos was of course halted.

For the transcontinental land-lines between Woomera and the west coast the joint project paid two-thirds of the cost of the run from Meekatharra to Talgarno, with the PMG paying the rest plus the cost of the long Perth-Meekatharra stretch. The lines themselves had already been laid, and the other work was finished afterwards. The result was a big gain for outback telecommunications, but a dead loss for the project. As for Talgarno, the caviar dinner proved to have been sadly premature. After the cancellation no one knew what to do with the desert base. The prohibited area itself was later used as a dropping zone for the Blue Streaks serving as the first stage of ELDO's Europa vehicle, but it was no longer necessary to fix where they came down with any precision. At Talgarno village all the buildings under construction were finished off, surrounded by a perimeter fence, and then closed up. For several years it remained totally intact like a Mary Celeste of the desert, its large powerplant ready to run and its kitchens ready for use with their brand new machinery cocooned in plastic sheeting. There were some vague plans to use it as a commando training school, and for a while the Americans considered using it to house the communications base later sited at North West Cape, but in the end it was totally written off. A tiny fraction of its cost was recovered by auctioning the assets. Even a decade later when ELDO itself had left Australia some of Talgarno still stood abandoned with the mess hall fully equipped with tables and chairs, blinds flapping in the windows of buildings perfectly preserved in the dry air, and the whole place a curious memorial to Britain's deterrent pretensions.

In London a couple of months after the news broke, Australian officialdom—in the shape of representatives from WRE, the Treasury and Supply—was perhaps a little soothed by an official recognition by the Chairman of CUKAC, Sir Steuart Mitchell, that 'the cancellation of Blue Streak as a weapon had come as a tremendous disappointment to Australians after their courageous efforts to get the range ready'.[17] But doubtless what really made their ears prick up was the assurance at the same meeting that a space research program might take its place, in which 'there was a possibility of a French interest'. In such guarded tones came the first intimation that a European satellite launcher was on the horizon. As it became reality, this great project gave Woomera's public image a lustre it had never had before. For a few years in the mid-1960s the launches of the big Europa space vehicle brought the town squarely on to the world stage, earning it the kind of attention that the media had previously reserved for the space activities of the superpowers.

NOTES AND SOURCES

1. Various widely disparate figures of the total cost of Blue Streak have appeared. Watkinson put the figure at £100 million at the time of cancellation, but he was imprecise as to what was included in this. Probably it did not include a share of Britain's joint project expenditures in Australia. According to the well-informed defence commentator David Divine, the development charges at the time of the contract placements were assessed at £50 million, but the estimates had risen to £160-200 million as early as 1957. By March 1960 the figure was £280-310 million and the Powell Committee declared that by the time it was fully deployed the total costs might reach £600 million, or around 4.5 thousand million pounds in 1986 terms. In 1960 the UK's total bill for public education from primary through tertiary levels was £895 million.
2. During a television interview, as quoted by Andrew J. Pierre, *Nuclear Politics: The British experience with an independent strategic force* 1939-1970, Oxford University Press, London, 1972.
3. Pierre, p. 171ff, explores all these strands in British strategic thinking with commendable lucidity.
4. File 5414/4/7 part 1 folio 5IB.
5. John L. Chapman, *Atlas: the story of a missile*, Gollancz, London, 1960, p.89.
6. In values of the mid-1980s at least $9.5 million. Appendix 'A' of a minute dated 1 August 1956 from the Secretary, Department of Supply to the Secretary, Department of Defence. Shedden Papers box 1395.
7. Butement's brief to the Minister for Supply is classified.
8. Letter dated 9 January 1959 from Minister for Supply to Minister for Defence. File 5414/1/5.
9. From a Ministry of Supply press release, 1958.
10. Figures from the SA Government Statistical Office averaged over the five years 1951-55.
11. Report dated 29 March 1960 from Security Officer Talgarno to the Regional Security Officer (SA). Information supplied by Defence Security Branch folder.
12. Harold Macmillan, *Pointing the Way* 1959-1961, Macmillan, London, 1972. In fact the Defence Committee did not conclusively confirm the cancellation until its meeting of 6 April. At that meeting the part Blue Streak might play in a satellite launcher program was discussed.
13. My account of developing UK attitudes to Blue Streak is heavily indebted to Humphrey Wynn, 'The RAF strategic nuclear deterrent forces: their origins, roles and deployment'. Ministry of Defence: Air Historical Branch (RAF) 1985. Unpublished MS.
14. Letter dated 31 July 1959 from Australian Minister for Supply to UK Minister of Supply. J. L. Knott Papers 1957-60. AA MP1472/8.
15. These exchanges take the form of a cable to Macmillan (recorded in a Department of External Affairs cablegram of 21 September 1959); a telegram dated 2 October 1959 from Macmillan to Menzies (via the Commonwealth Relations Office); and a communication dated 5 January 1960 from Macmillan to Menzies (recorded in a letter dated 7 January from the Ministry of Aviation to the Senior Supply Representative, Australia House, London). AA MPI627 file AMB/1103.
16. Records of the Cancellation Symposium of 10 May 1960. J. L. Knott Papers 1957-60. AA MP1472/8.
17. Minutes of CUKAC meeting 48 of 8 June 1960.

23 Woomera's heyday: *The* ELDO *Program*

A SATELLITE LAUNCHER FOR EUROPE

Australia took the news of the Blue Streak cancellation hard. It was not just the wasted money, although a good proportion of the £9.5 million it had contributed under the joint project agreement over the current financial year (1959-60) had gone on building Talgarno and Area 6 and installing the elaborate tracking and measuring instruments along the length of the Range. Rather, it was rather the sense of betrayal and inferiority; the sense that Australian resources could be summoned up, consumed and then tossed aside according to decisions made in another country. In public the Menzies government preserved a stoical silence about the matter except for a brief statement of record, but not so some others. Chapman Pincher, the influential British commentator on defence matters, heaped coals of fire on official heads by declaring roundly that 'the whole Woomera rocket range will be a virtual write-off'.[1] Harry Messel, the flamboyant Professor of Nuclear Physics at Sydney University, happened to be in London at the time and he told the British press that the future of Woomera, now in doubt because of the cancellation, was 'the biggest hot potato in Australian politics for years', charging that Britain had sold Australia down the river without hesitation when it found that a cheap American missile was in the offing. The only way Britain could redeem itself, he said, was by announcing at once a space program based at Woomera using the discarded weapon.[2] Messel's opinion was given wide and approving coverage in his home country.

These were exaggerated remarks, made in the heat of the moment. Pincher's prediction that Woomera would close down was nonsense since the bread and butter work of the Range showed no diminution at that time. The development and acceptance trials of the next generation of the Bloodhound and Thunderbird weapons, and the continuing work on Blue Steel, guaranteed Woomera's survival well into the decade ahead. The storm blew over quickly enough as the journalists lost interest, and after a few months Supply Secretary John Knott could report with relief to his counterpart in the UK Ministry of Aviation:

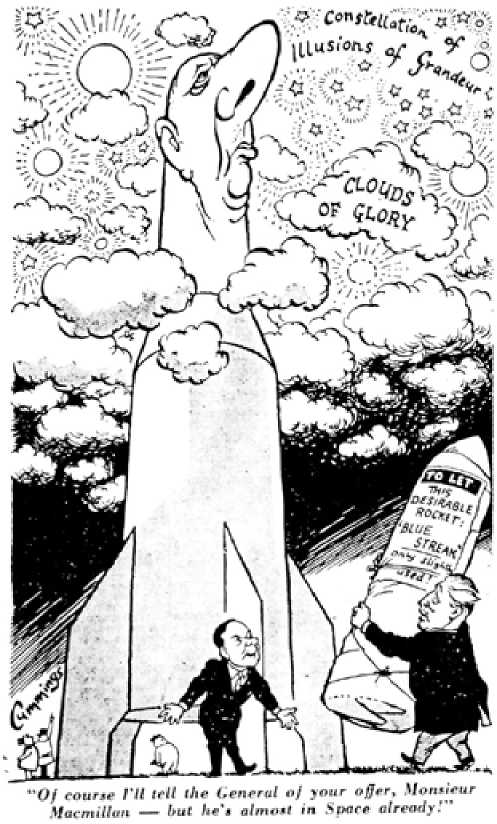
> The winding-up has been relatively painless. My own Minister [Alan Hulme] was very good in dealing with all parties concerned and what might have blown up into a political mess has quietened down surprisingly well.[3]

By this time denunciation had given way to lobbying to encourage the British government to announce a space program, from quarters as various as the British Interplanetary Society, the firm of De Havilland, the Australian Academy of Science, and Professor Bernard Lovell of the Jodrell Bank radio observatory. Some of these appeals were more disinterested than others, but they all used the same argument. Having spent so much, why waste the expertise? Why not spend more, not this time on a weapon which everyone hoped would never be used, but on a satellite launcher which might one day offer a very marketable service?

There was in fact nothing new about this idea. Informed circles within the British government had been alive to the possibility of using Blue Streak as a launcher during the assessments leading up to the cancellation. In January 1960 the Minister of Science, Lord Hailsham, had written to Defence Minister Watkinson asking for news about the future of Blue Streak. Hailsham appreciated that space research plans could not be allowed to deflect defence policy, but he advised Watkinson that he was being subjected to a good deal of pressure from several quarters to announce an all-British satellite launcher. Indeed, the Prime Minister himself had aired the topic in public. Late in 1959 Harold Macmillan had referred to Britain's making some independent effort in space, possibly by adapting one or more of its military rockets. Shortly after the cancellation Macmillan put up the same proposal privately to Menzies to gauge his reaction. Macmillan admitted that the expense would be heavy, but he thought that, apart from its other virtues, the enterprise would help to deflect public criticism in both countries over the cancellation. He put the cost of a worthwhile program at more than £60 million spread over four or five years, and the benefits were, he knew, highly speculative. But there would be political costs in both countries if Blue Streak was not put to some use; national and Commonwealth prestige, though an intangible factor, could not be neglected.

Thus it can hardly be denied that the choice of Blue Streak as the first stage of an orbital launcher was influenced by political considerations and by Britain's wish to preserve the health of its armaments industry. A cynic might even charge that it was a face-saving exercise. Still even if Blue Streak was, as Chapman Pincher said bitingly, being 'hawked around the Chancelleries of Europe' that does not mean it was a bad engineering decision. Quite the contrary. Almost from the beginning the Blue Streak development team had recognised that their rocket could easily be modified for a new role and, after the first Sputnik went into orbit in 1957, official studies were made both on altering it to serve as a first stage and on the design constraints for the second and third stages above it. The concept was known briefly as Black Prince and is treated in more detail in Chapter 25, whose subject is the all- British satellite launcher, the ill-fated Black Arrow. Black Prince died soon after conception when the Cabinet decided that it would be too expensive to bring to birth, but from its demise sprang the notion of the international consortium which became the European Launcher Development Organisation, or ELDO.

For Britain particularly, the time was ripe for such a venture into pan-European co-operation. The Common Market was an indicator of growing trade links between the European nations, and the Conservative government looked forward to joining the Market one day. (Whether Britain's offer of Blue Streak was a diplomatic dowry in the wooing of Europe is unclear; if so it did not have the desired effect, for General de Gaulle vetoed Britain's application to join the European Economic Community in January 1963.) A number of co-operative European scientific and technical ventures already existed. There was the British-French Concorde project, the European Centre for Nuclear Research (CERN); the European Space Research Organisation (ESRO) which would surely be in the market for a satellite launcher, and an association of European firms set up as a lobby group to promote



This is how Cummings in the London *Daily Express* (October 1960) viewed the early British endeavours to interest France in a European satellite launcher using the abandoned Blue Streak weapon. (*Express*) space research (EUROSPACE). Then there were the United Nations bodies devoted to space: the Committee on Space Research (COSPAR), and the Committee on the Peaceful Uses of Outer Space (CPUOS)—both Britain and most European nations had representatives there. After the spectacular achievements in space of the two superpowers in the late 1950s, the whole of Western Europe had suddenly become interested in space technology. But getting into space was notoriously expensive and beyond the reach of smaller nations, and therefore the idea of an international consortium seemed sensible enough. The United States and the Soviet Union were enjoying a monopoly in powerful launchers, and the former particularly was reaping the benefits of a stimulated aerospace industry and all sorts of technological spin-offs. Within a few years more Americans would be working in aerospace than in the motor industry. For their part the Russians had led with the first satellite, the first rocket to achieve escape velocity and the first manned orbital flight—an impressive record. But the Americans were soon to take a decisive lead. President Kennedy's statement of intent to land a man on the moon by 1970 came in 1961 when ELDO was first being mooted. Over the next few years when ELDO was developing and testing its vehicle, Europa I, the Americans' Apollo project moved into top gear, so that two-thirds of NASA's huge budget was being expended on manned spaceflight.

Applied space research was going on elsewhere in the world too. The Japanese were not far from achieving a satellite launch with their Lambda rocket, and even the Egyptians were talking about a modest space program with German help. Europe had suffered a haemorrhaging of some of its best scientific talent to America and an indigenous program like ELDO might encourage more of it to stay at home. There was also a certain amount of mild European chauvinism at work; as one of the ELDO publicity brochures put it, 'European scientists were responsible for most of the discoveries which make possible the conquest of space today'.[4] Was it thinkable that the nations of the Old World, that had nurtured Galileo and von Braun, Newton and LaGrange, could not muster at least a modest effort into space? ELDO gave Europeans the chance to make their mark collectively. So far they had spent only tiny sums on space. Even in 1964 the expenditure of all of Western Europe amounted to barely 2 per cent of the American figure and in proportion to the population was even smaller than that. Britain and France, the European leaders, were spending less than one tenth of 1 per cent of their GNPs on space; America was spending just over 1 per cent.[5] No question but that Europe could afford to do more: the ELDO nations held 20 per cent more population than the US and were at least half as rich. Nor were they starting at first base. Not only was Britain's costly and fully developed Blue Streak going begging, but the French had an ambitious national space program working out of its Hammaguir range deep in the Sahara. Within a few years they would succeed in orbiting a series of satellites using the home-grown Diamant rocket, including the wholly successful Diapason with the respectable weight of 38 kilograms. France achieved all this quite alone after founding her range at about the same time as Woomera, and her space program was by far the most ambitious and successful in Europe.

The most powerful factor in the formation of ELDO was the growing awareness that the earth satellite was potentially far more than a beeping symbol of patriotism in the sky. It was about to become the supreme information gathering and communications tool of the age. This new scientific genie promised to revolutionise global communications and to spread education and propaganda to the developing countries. Crop and marine resources could be photographed and mapped from space. Weather forecasting and storm warnings would become precise and reliable. New navigational aids based on satellites would make it impossible for ships and aircraft to lose their position. And this is not to mention the supreme importance of satellites for military purposes: surveillance from space at remarkable levels of resolution, killer satellites, orbiting bombs and the rest. All those applications which twenty years later have become commonplace had then the charm of novelty mingled with the chill of the unknown.

For the new satellite technology brought anxieties in its train as well as many golden hopes. Only the two superpowers had the rockets capable of boosting the heavy communications satellites up into high geostationary orbit, and though the Americans had repeatedly said that they would launch European satellites whenever they had spare capacity, this promise was regarded dubiously in some quarters; not necessarily through doubt in America's good faith, but from a fear that frequent launches for Europe might not fit into the Americans' crowded schedule. In any case, so the argument went, for as long as Russia and

America enjoyed their monopoly in satellite launching they had the final control over the information beamed down from orbit. The thought of a Russian satellite broadcasting Marxist propaganda unhindered into every Indian village that could afford a radio or television set was not a comfortable one; and—for the French in particular—neither was the thought of popular culture with an American accent being transmitted into francophone households. It seemed axiomatic that to gain a voice in space a nation, or a group of nations, must have its own means of putting satellites into orbit. This urge to independence was the reason why ELDO looked attractive, and was certainly the main reason why France joined it. As the Secretary General of ELDO, Renzo Carrobio di Carrobio, put it in 1966, 'to be able to develop launchers of one's own is a threshold below which there can be no independent space policy'.[6] The motive for the founding of ELDO could not have been put more succinctly, and it quite overmastered any sober consideration of the uses to which a Europa-launched satellite could be put. One notion was that it might be useful for meteorological work. Even in 1962 it was conceded that the American Tiros and Nimbus systems would offer an adequate service, but one thought was that a complementary system tailored to European interests might be useful. Then there were the navigational possibilities: a European version might be used for supplying positions to ships and aircraft. At best these were all speculative uses, but all doubts were assuaged by the assurance that solid benefits would emerge once Europe began to move into the high frontier of space. The optimists argued that it is always the unpredictable spinoff benefits that turn out to be the most valuable in the end, and the history of technology shows that these benefits come faster when working in a challenging environment. All well and good to talk about economic viability, but one must sometimes take the long view. If quantifiable economic benefits had been the sole criterion, would an aeronautical industry ever have been set up in Europe after World War I?

BRITAIN TAKES THE INITIATIVE

All in all, then, the signs looked good to the British; and immediately after the cancellation of Blue Streak their Minister of Aviation, Peter Thorneycroft, started to cast about for support for the launcher scheme. Possible partners could come from the Commonwealth or from one or more of the European countries. According to diplomatic information supplied to Menzies, Thorneycroft was not intent on pursuing a launcher consortium at any cost. His government was not afraid to scrap the project completely if it had to, and Blue Streak along with it; but for the present it was 'thinking in terms of France in particular and maybe Germany coming to the party'.[7]

Of the Commonwealth countries Australia turned out to be the only one even remotely interested. The most negative view within the Menzies Cabinet was that the whole proposal had the look of a salvage operation. But for a change of military plans, would it ever

UK Minister for Aviation Peter Thorneycroft (*centre*) meets Boswell during a 1960 visit to Australia to discuss the proposal.

have heard of Thorneycroft's scheme? Was his government not so much originating it, as being shoved into it? Menzies himself thought this was a base and utilitarian view. If Britain decided to go ahead, with or without a partner, in a program which needed Woomera, his government certainly should not say that the Range was unavailable. Therefore the reply to Britain in September 1960 was worded diplomatically:

> Australia would not wish to contribute funds to a European SLV [Satellite Launcher Vehicle] organisation in view of its already heavy commitment to Woomera and an urgent demand for other development expenditure (e.g. water supply and conservation, transport, communications, mineral resources, agricultural development and the establishment of new industries). The growth of population in Australia is making these matters more pressing . . . however, we would not wish to stand in the way if it were the desire of the Europeans that Woomera should be used.

But, as usual, Menzies drove a hard bargain. It was made clear that the price of using Woomera would be full membership of any 'space club' which might be in the offing.

That left Europe, with France the first target. At first France, with a full national space program of its own to run, showed little enthusiasm for a collaborative exercise; but after lengthy negotiations an agreement was reached whereby Britain would supply a Blue Streak first stage while the French would design a second stage based on an existing sounding rocket, the liquid propellant Veronique. All this took what seemed like an unconscionably long time to WRE. The Establishment was pressing urgently for a decision, saying that the more staff were diverted from the aborted Blue Streak the more the effort that would be needed to recover the pace. It would be unfortunate indeed if the rumour got abroad that Australia was incapable of carrying out on schedule its part in any international venture.

At the end of January 1961 Britain arranged a conference in Strasbourg which was attended by representatives from ten countries.[8] Australia did not attend: it was thought undiplomatic for it to do so when the question of whether to select Woomera was purely a decision for the European partners to take. Actually the awareness that Australia was waiting in the wings, as it were, did put Britain at something of a disadvantage at Strasbourg. The prospect of Australia, Britain's joint project partner, being a full member of ELDO while contributing nothing to its funds, exasperated some of the Europeans who could—and did—argue that they, unlike Australia, were still labouring under the expense of post-war reconstruction yet were being asked to make engineering and other facilities available as well as pay. But these arguments did not carry the day. In the event Woomera was selected and Australia later became an independent member, with ELDO undertaking to reimburse Australia for the use of joint project facilities (such as accommodation) at Woomera, just as any other third party Range user did.

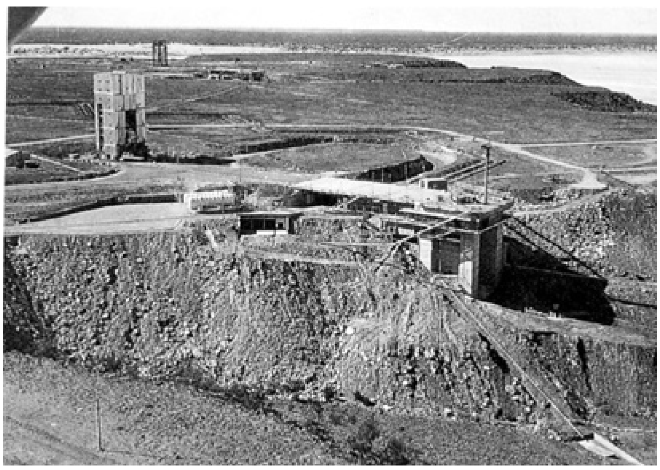
Later the same year, in October-November 1961, a diplomatic conference was held in London at Lancaster House, attended this time by ten European nations and Australia. At Lancaster House a draft Convention and details of the initial program were hammered out. The satellite launcher was to take the form of a three-stage rocket powerful enough to put a small probe into an escape trajectory or to crash a 45 kilogram instrument package on to the moon. (The Soviet Union's Luna 2 had achieved this feat two years before.) Closer to earth, Europa should be capable of putting a one tonne payload into a low 600 kilometre orbit over the poles, or a very much smaller 200 kilogram satellite into the high equatorial orbit suitable for telecommunications. The latter weight limit precluded the launching of a working communications satellite, for at the time these were very much heavier than they later became; but such a satellite could be used for research. It might, for instance, carry a stabilised telescope for ESRO to study ultraviolet radiation from the stars. ESRO (the pure research organisation founded about the same time as ELDO but with ten member nations instead of seven) had already published an elaborate program involving no fewer than 400 sounding rockets, six small satellites, eight bigger satellites, seven probes and a large orbiting laboratory. Surely here would be work aplenty for Europa—although as a matter of fact ESRO had already taken a lot of bookings on American Scout and Thor-Delta rockets and went on to use them widely in its work. The development and construction of Europa would be divided among the members, with Britain providing the first stage, France the second, West Germany the third, Italy the satellite carrier, Belgium the tracking and guidance station, Holland the long range telemetry systems and Australia the Range facilities. Ten firings would be made from Woomera, starting in 1963 and culminating with the insertion into orbit of a dummy satellite in 1966. The program would be entirely commercial and scientific, without any military objectives, and all the garnered information would be available to the members and to other research organisations like ESRO.

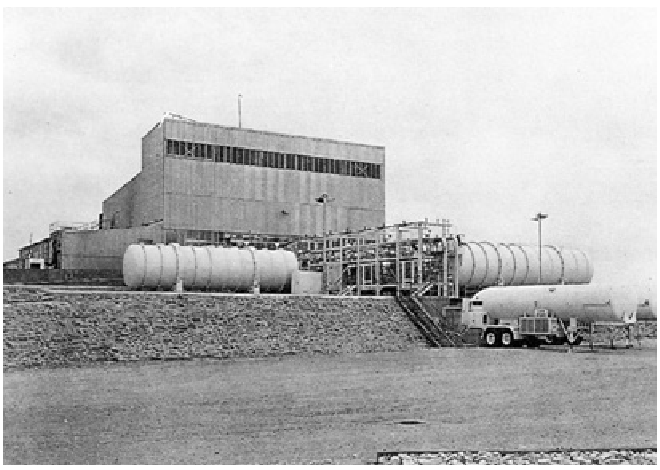
How much would the launcher cost? The estimate put up by Britain was a modest sum: £70 million sterling spread over five years. Even at the time this should have been recognised as far too sanguine a figure—and it included a large contingency allowance!—bearing in mind that the work was to be spread around the laboratories and workshops of half a dozen countries and the Australian outback. Britain, with the painful experience of Blue Streak still in the foreground, should not have been in an optimistic mood. The suspicion is irresistible that the figure was pitched as low as possible to invest the proposal with the maximum appeal.[9]

These arrangements were not finalised until 30 April 1962 when the Convention was formally opened for signature. Even after that was done legal difficulties prevented the Convention becoming binding for almost two years, whereupon the agreed division of costs fell thus: Britain, 38.79 per cent; France, 23.93 per cent; West Germany, 22.01 per cent; Italy, 9.78 per cent; Belgium, 2.85 per cent; Holland, 2.64 per cent. Australia's contribution, though zero in terms of hard cash, was by no means insubstantial. It had to open up a second flight path for the orbital firings, running north across the continent to the Gulf of Carpentaria and beyond into the Arafura Sea. At Lake Hart it gave ELDO the exclusive use of all the Blue Streak facilities: the launcher itself, the test post and fuelling services, the equipment centre with its monitoring rooms, offices and workshops, a fully equipped canteen to serve 150 people, and all the ground services. At Woomera it offered a large air separation plant with vacuum insulated storage tanks for the 100 tonnes of liquid oxygen and nitrogen it produced each week, plus the special road tankers for transport. The necessary staff, offices and laboratories were allocated at Salisbury. The value of all that was at least $9 million. The agreement was that ELDO would pay for any new facilities required at Woomera village, and also for the use of the instrumentation, lodging and other services at rates covering the costs. ELDO also made a contribution to the fixed expenses of WRE.

Thus was ELDO born. As might be expected, such a large international collaboration gave rise to an elaborate bureaucracy to administer it, though whether it had to be quite so unwieldy is questionable. At the head was a Council, based in Paris and made up of two representatives from each of the member countries. The Council decided general policy with the aid of sub-committees handling particular technical and administrative problems. These also were composed of representatives from each country. A Secretariat executed Council policy, and its members moved to Paris in October 1962, to a grand but sparsely furnished building in Rue La Perouse, which was formerly the headquarters of the SS in occupied France. Close by was the superb Hotel Majestique in Avenue Kléber, then being converted into an international conference centre; this became the venue of the many ELDO meetings requiring multilingual facilities. Australia seconded some fifteen skilled people to the Secretariat staff, mostly from WRE; all of them were under contract to the Secretariat and responsible to ELDO alone during the period of attachment, and most spent some

The expensive Blue Streak facilities that Australia contributed to ELDO included (*below*) the Launcher 6A complex and (*below right*) the air separation plant that produced liquid oxygen and nitrogen for the first stage of Europa I.





years living in Paris.[10] It was May 1964 before these complex arrangements were completed and the Council was able to meet for the first time.

The foundation of ELDO, with Britain as the senior partner, was greeted with the greatest approval in London. One newspaper, in a patriotic rush of blood to the head, compared ELDO to the days of the merchant adventurers when the Crown and the ship-owners put up their risk capital to sail unknown seas in the hope of reaping golden rewards. It was left to the *London Times* to ask plaintively the vital question:

> What the public wants to know is whether there is any good reason why British research instruments must be launched into space by specifically British rockets. What justification, apart from the doubtful one of prestige, can there be for competing with America and Russia in the production of satellite launchers, when both countries have an irretrievable lead on Britain?[11]

True, Europa was not going to be a British rocket; but Britain had by far the broadest experience in rocketry among the partners and its provision of Blue Streak meant that it would be exercising the most influence over the entire Europa design. Then again it had the strongest motivation to make ELDO work and the strongest need to benefit from it. Britain's financial contribution was the biggest and, far more so than the other two main members, it was putting most of its space eggs into the ELDO basket. Outside of ELDO Britain had only a very small national program costing about $5 million in 1966, or about one-eighth of the amount it was contributing to ELDO. Germany, by contrast, retained about a third of its space expenditure for a national program and France's expenditure on ELDO was only a third of its total space effort. In 1965 France was spending nine times as much as Britain on a national program. So as ELDO's problems mounted it is not surprising that many Britons began to query whether the objectives of the program had been worked out thoroughly enough.

ELDO COMES TO WOOMERA

In July 1962 the first ELDO planning mission visited Australia so that the Europeans could see what was available at Salisbury and Woomera. They declared themselves most pleased with what they found. For their part the Australians were very pleased to act the host. They did not see themselves as simply hirers or hoteliers to ELDO. They too were interested in space technology in its own right, recognising that few countries had as much to gain from satellite technology as theirs. Apart from knitting a remote country more closely into the international communications networks, the satellite held out to Australia the first economically viable hope of providing a telephone and television service across the thinly populated interior. The Minister for Supply, Alan Fairhall, had no trouble convincing Parliament that Australia's membership of ELDO was an excellent bargain. It was, he said, a wonderful chance to get in on the ground floor when it came to launching telecommunications satellites. Benefits would surely flow to industry in the way of advanced engineering, chemical and electronic techniques. Australian scientists would be able to work with leaders in their field and might not need to go overseas. It would also bring a lot of work to Woomera, where the Range facilities and staff were already in place and had to be maintained anyway. Nor was Australia committing itself to anything lengthy; it was free to withdraw after the first program without penalty. The Opposition found little to quarrel with in this reasoning. Perhaps both sides of the House felt that the coming of ELDO would salve the hurt caused by Blue Streak's cancellation and would also save officialdom the embarrassment of having to declare redundant all the fabulously expensive Lake Hart facilities.

Alan Fairhall, Australian Minister for Supply in 1962 (PA).

Most of ELDO's presence at Woomera during trials consisted of the national teams, each team being autonomous within its own area of responsibility and free to communicate with its parent organisation. The teams varied in number and composition from firing to firing but totalled about 300 on occasion, ranging from 150 Britons down to five Belgians. The influx of some hundreds of ELDO people for a Europa launch and their dispersal afterwards put a cyclic pressure on the village's resources. The presence of large trials teams were not new to Woomera, but ELDO's demand for air transport was sufficient to fill several aircraft, and extensive canteen and ground transport services had to be provided at the launch area. There were also special demands from the Range for canteen services at Koolymilka to match the extended working hours, and at Mirikata to accommodate trials staff there. The catering staff at Lake Hart had to supply a choice of courses continuously throughout the day and night during peak periods, but the general agreement was that the quality of the catering was excellent and it more than satisfied the varied preferences of the different nationalities. In the village the ELDO people were mostly accommodated in a new purpose-built mess. It was understandable from a joint project viewpoint, for security dictated that control should be exercised over contact between the staff of a large civilian project and the other military work at the Range; the ELDO authorities may have required it too. Yet this departure from traditional practice was unfortunate in that it did separate the WRE and ELDO people during their leisure hours and it hardly encouraged social interaction. Members of the Australian national team in ELDO were members of the ELDO mess, but the Woomera population generally was not allowed in without an invitation. As few Woomera folk other than those employed at Area 6 had any contact with the Europeans, such invitations were rarely forthcoming. Similarly, members of the national teams rarely found their way into joint project messes. It was natural, too, that the Australians should feel some resentment at the ELDO men's enjoyment of their spanking new building which made a sorry contrast of the other messes.

E. C. ('Monty') Montgomery, WRE manager for the ELDO project.

As far as the operation of the Range was concerned, ELDO was just another Range user and, apart from the size and complexity of the Europa vehicle—easily the largest ever launched there—the trials program, handled by Missile Projects Group, was relatively straightforward. WRE's Director, Bill Boswell, took a particular interest in the Europa program and did his considerable best to smooth relations between his staff and ELDO's. His successor, M. W. Woods, established in 1965 a special team called Management ELDO Group under E. C. Montgomery; before this date the requirements of Europa were looked after by the Projects Assessment Group in the usual joint project fashion.

The coming of ELDO certainly produced plenty of work both at the Range and in the village. The pace of activity was fierce and morale high. Distant posts had to be manned for long and uncertain periods, safety warnings issued to landholders and shipping within flight corridors, communications links set up with distant tracking stations right around the world. Most of the trials took place early in the morning, to obtain good meteorological conditions and as many daylight hours as possible should anything go wrong. The firing sequence usually started at 6.30 a.m., so throughout the preceding evening and night the life of the village was disturbed by heavy traffic and the general air of bustle from which few could remain aloof. The procedure was for a group of Range and ELDO staff to assemble at the Woomera meteorological office at midnight to examine the weather forecast. A flashing indicator at the village exit for the Range then informed everyone of the position: three lights meant that the trial was cancelled and they could return to bed; two that there was a change of schedule and so on.

At the launch area some very new arrangements had to be made. Handling liquid oxygen was by this time fairly routine at the Range, but the fuelling teams had to deal with long delays while the upper stages were fuelled. Many of the launches were preceded by aborts: one Europa suffered no fewer than thirteen of them before it was finally dispatched. To allow for boiling-off, as much as 160 tonnes of liquid oxygen were stored at the foot of the launcher. Gaseous nitrogen was also used in large quantities to pressurise the propellant tanks. To save the cost of pressurised storage vessels, the nitrogen was stored in the actual pipelines between a converter plant and the launcher. The pipes zig-zagged along the ground and were duplicated to give enough storage volume. The hot climate at Woomera was a problem with the fuel and electronics in the upper stages of Europa, and they had to be air conditioned via an extra umbilical mast. The second and third stages of Europa used hypergolic fuels which ignited spontaneously when mixed with an oxidant. The vapours were poisonous and the fluids caused even nastier burns than HTP, so the safety precautions had to be very strict indeed. The filling points were located so that the fuels and oxidants were delivered from tankers on opposite sides of the emplacement for piping via the umbilical to the upper stages. The operators were clad in what were practically spacesuits, pressurised with their own air supply, temperature control and communicators. Fumes vented from the upper stages passed through water scrubbers before being released to the atmosphere. During fuelling a doctor hovered close by in a helicopter, and the French had insisted on a rapid escape route from the servicing tower, in the form of a taut wire rope stretching diagonally to the ground, with a number of 'geronimos' to use on the slide to safety. The contraption looked so terrifying that few could be induced to practice the escape routine. The men working on these hazardous tasks worked a strict 8-hour day. With a smooth uninterrupted countdown this mattered little, but if there were many aborted firings the rest of the staff found themselves working long hours.

Although an enviable record was maintained, without a single instance of serious injury or damage, there were some anxious moments. On one occasion a valve left open allowed the entire contents of a kerosene tank to flow into the bed of Lake Hart. A much more frightening incident opened when the engineer in charge of the plant which distilled liquid gases from the air at Woomera phoned Salisbury with unwelcome news: he had found small needle-like crystals in a tank containing 80 tonnes of liquid oxygen. The crystals were frozen oil; oil that had seeped in from a leaky seal. Oil and LOX is such a potentially explosive combination that the maintenance engineers were allocated a checked weight of lubricant when they started their shifts. Probably nothing would happen while the frozen oil was left alone. But if it were to be warmed even very slightly, as it might be by friction or compression when the outlet valve was opened, the resulting explosion could devastate the whole plant. By great good fortune the emergency had arisen on the day before the Christmas stand-down when Woomera was emptying for the holidays. Next morning four senior engineers arrived post-haste from Salisbury to consider the problem. The liquid oxygen had to be drained off somehow. Someone had to open the outlet valve just a fraction, to let the contents flow into a nearby pit. The engineer of the plant bravely volunteered for this job, which he managed from a distance by tying ropes to the valve handwheel, leading them well away to a place where he could crouch down well below the tank level and escape if anything happened—maybe. It was a heart-wrenching moment when the wheel was eased round a fraction and the fuming LOX began to spill out. Nothing happened. In the New Year the tank was cleaned and found to contain several pints of oil. Restoring the system, including the 14 metre long stainless steel tank, was a long and tedious job, but a good deal easier on the nerves than simply opening that valve.

Europa's flight safety equipment was elaborate, as befitted a large three-stage vehicle, but it worked in much the same way as the systems fitted to all the large rockets flown from Woomera. A transponder was fitted in each of the first and second stages, so that each could be tracked by an FPS-16 radar at Red Lake and Mirikata respectively for safety tracking. There was a break-up system which comprised a complex duplicated arrangement of WREBUS receivers in both the first and second stages, cross-connected in such a way that a command from one of the two ground transmitters would trigger explosive charges in the propellant tanks and elsewhere in the vehicle. There was also an automatic system designed to operate as the third stage re-entered the earth's atmosphere. As with all the break-up systems, WREBUS was not intended to shatter Europa into harmless fragments if it strayed off course, but to make sure any residual explosives and propellants on board were destroyed. The third stage had no separate command break-up as it would fall in the sea after separation if it failed to go into orbit.

Generally relations between the national teams and between the teams and the Range authority over matters of safety were cordial. There were a few points of friction, such as the mandatory use of English during launch preparations. On one occasion the control officer asked the French team if they were ready to proceed. 'Oui', they replied. Control repeated the question. 'Oui', came the defiant response again. Determined to get a response in English.

The French team, responsible for the second stage.

Control persisted: 'Are you ready?' This was too much for one of the Frenchmen. 'Oui . . . bloody yes!' he snapped. Occasionally a dispute arose over the rigorous and, some said, too puritanical safety precautions. The bans on alcohol and smoking in operational areas were enforced to the point that the French were denied a request to drink wine with their meals at Area 6. Another Frenchman liked to puff on an aromatic Gauloise while fuels were pumped, and WRE safety regulations were invoked to stop him. One issue that had nothing to do with safety concerned the presence of servicemen at Lake Hart. It was a tradition dating back to the first days of the Range that the launcher crews were supplemented by a small detachment of the Army, which was a convenient source of labour. During Phase 2 this became a contentious issue as the Convention said that ELDO had no military aspects to it, and the Range was obliged to introduce civilian launcher crews for the first time in its history. A small WRE staff was located permanently at Area 6 to solve the occasional tense problem that arose when one or other of the national teams felt accused or frustrated by a ruling. During Phase 2 WRE took great trouble to make sure that the Europeans were happy with the services that it and the Woomera administration provided for ELDO. Generally things went smoothly, although the decision, described later, to cut down Europa's F4 flight reinforced some suspicions that WRE was absurdly over-cautious.

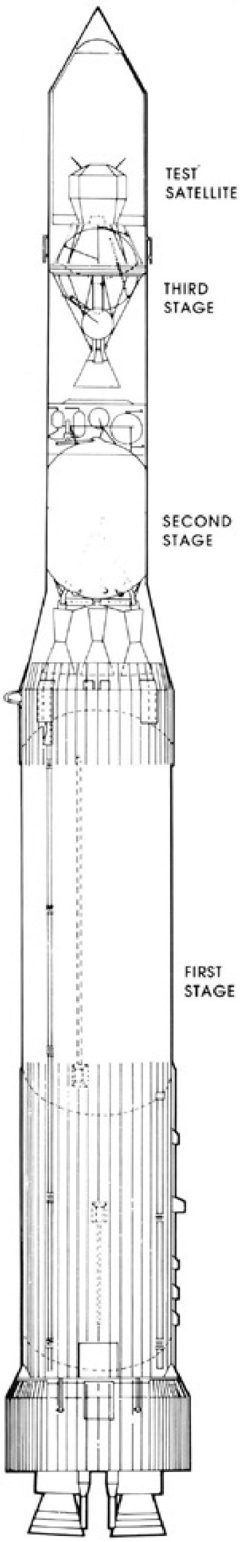
The arrival of ELDO had other, more subjective effects. It was a stimulant to life both at the Range and in the Village. Woomera as a 'space town'! The phrase started to sound less like journalistic hype and more like sober reality. Optimism and morale reached their highest pitch. It did not seem altogether absurd to predict that Woomera might one day see manned spaceflight. The population of the village rose to its maximum—a little more than six thousand—and for some time Woomera Airport was the busiest provincial airport in Australia, echoing to a babble of European tongues. New blocks of flats and detached houses arose in the biggest surge of building that the village had seen since the early 1950s. The ELDO personnel brought a pleasing cosmopolitanism to the village, helping to alleviate its rather stuffy Anglo-Saxon flavour, and most of the foreigners thought the facilities were good—especially the Frenchmen who had worked at the spartan Saharan range: Woomera struck them as quite idyllic by comparison. Nor were the ELDO Europeans the only new strangers in town. American drawls were now being heard too alongside the French, German, Italian and Dutch. Throughout the 1960s NASA was building up its network of tracking stations for its manned space enterprises and deep space research programs. Near the dry salt lake of Island Lagoon 25 kilometres south of the village was one of three Deep Space Instrumentation Facilities around the world. The great dish aerial at Island Lagoon was used, among other things, for receiving signals from the Mariner Venusian and Martian probes and the Ranger spacecraft. Nearby was the Minitrack satellite tracker, one of thirteen such around the world feeding information back to the Goddard Space Flight Center in Washington. All these glamorous developments added an additional excitement to the ELDO effort, for they implied that the exploration and exploitation of space was at last evolving into an international, or at least a Western, enterprise.

THE DESIGN FEATURES OF EUROPA I

Right at the beginning of ELDO it was whispered that Europa I was obsolete before its design had begun: that even if it were a total success it would only match American and Russian achievements now a decade old. But to most eyes Europa made good sense, given the limited resources the ELDO partners were prepared to put into it. Modest though it was, it would at least give the ability of launching 1 tonne payloads, and after the R&D phase was complete in 1966 or 1967 Europa would be good for five years or more of operational service. To counter criticism that Europa would be useless as a communications satellite launcher, some early research work went into seeing how its performance might be increased later. One way was to attach a cluster of small solid propellant boosters to the rocket body. This was a tried and tested method with guided weapons, but it might produce guidance problems. The other way was to use high energy propellants in the upper stages, perhaps a LOX/liquid hydrogen combination; but this was moving on to unknown ground and would certainly take a lot longer to develop. Even more speculative was the idea of electrical, or ionic, propulsion. In 1967 ELDO renewed its examination of a prospective new family of launch vehicles, still using Blue Streak as a first stage, but nothing came of these. During the entire career of ELDO on two continents, the Europa I rocket was its only vehicle.

In its final form Europa I consisted of three liquid propelled stages, all steered by gimbaled combustion chambers. Its all-up weight with propellants was 106 tonnes. The design limitations on the upper stages were quite rigorous, especially as regards weight. Blue Streak had after all been designed to carry a warhead, not the 16 tonne mass of two extra rocket stages and a satellite. The French second stage, Coralie, used two propellants called nitrogen tetroxide and unsymmetrical dimethylhydrazine (UDMH). They were forced into the chambers not by pumps but by gas pressure in the tanks. Coralie had four rocket engines, each with one degree of freedom, and controlled by hydraulic pumps. Its structure was of steel, nothing else being readily available, and the design was frankly cruder than either the first or the third stages. The French regarded this as a plus: a robust stage built like a rainwater tank, they said, would be more reliable than the tricky British and German engineering. In flight the upper stages were separated from the first stage by a separate little solid fuel motor whose exhaust caused the explosive bolts linking the sections to detonate. The combination of pressure and thrust ensured proper separation before the main motors ignited.

The Germans had some special problems. Rocket engineering in West Germany had been almost dormant since the end of the war. All the most brilliant engineers in the field had left for America or the Soviet Union and, with military ambitions closed to them, the Germans had had no incentive to make good the loss: all their human and material resources had been given over to the task of post-war development. Thus, unlike France and Britain, Germany had practically to create an industry from nothing to do the work for ELDO. The third stage had to save every possible gram of weight, and the specifications were very exacting. Furthermore the lead time was short. The development program called for four dummies to be launched in 1965 and four complete vehicles in 1966. The Germans chose to let out the design and production of the third stage on contract to a consortium (ASAT) formed by two firms, one in Munich and the other in Bremen, with headquarters in Munich. One company, Entwicklungsring Nord, took on the structure, tank system, fuel feed system, main engine and correction engines. The other, Boelkow, took up the attitude and guidance systems, booster telemetry, control system and another version of the correction engine. The oxidant was again nitrogen tetroxide and the fuel a product chemically similar to UDMH called Aerozine. Both of these highly reactive compounds were stored in a single spherical container of aluminium (later titanium) 170 centimetres across, on either side of a thin metal membrane. From here the propellants were separately fed by the pressure of helium gas to three motors, one for propulsion and two little vernier motors for positioning. Firing the main motor detonated the explosive retaining bolts and gave stage separation. The vernier motors developed only 50 kilograms weight of thrust each, but sufficient to move the third stage into high orbit if required. Guidance of the upper stage was under the control of a simple computer which stored the trajectory data and a programmer to start and control all the auxiliary systems. The commands could be overridden from the ground.



Europa I used Blue Streak as first stage and a French Coralie rocket as second stage, topped by a German third stage and an Italian test satellite.

The West German third stage team.

On board also was a transponder for radar tracking and a telemetry unit. Altogether it was a beautiful piece of precision engineering.

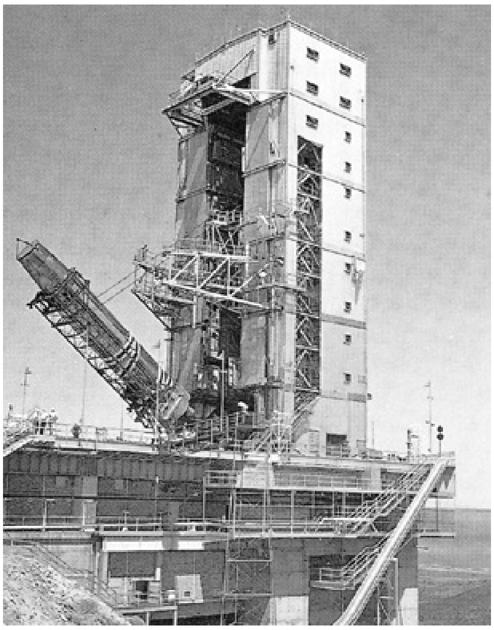
The satellite, designed and built by the Italian Centre of Aerospace Research at the University of Rome, was to be a test vehicle only, to garner information on guidance and separation and to give the launching and tracking crews some practical experience. Physically it had the shape of a polyhedron with solar cells on the rectangular outer faces. In flight it was protected by fairings against heat and buffeting. The fairings were fibreglass topped by a stainless steel nose cap and weighed about 330 kilograms. They were jettisoned during the second stage burning once the rocket was outside most of the atmosphere.

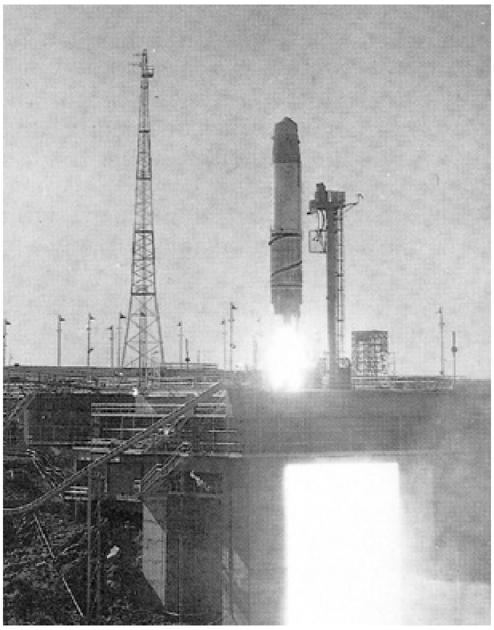
THE TRIALS OF EUROPA: THE FIRST PHASE

A total of eleven firings were made under ELDO's program at Woomera, though the first was only a Black Knight launched into an impact area near Mirikata to test the safety systems. The ten main flights were divided into three phases. This first phase consisted of three flights of Blue Streak alone, with a planned impact point in the Percival Lakes region of the Great Sandy Desert, which was within the Talgarno Prohibited Area. There was some difference of opinion about this destination. The thinking at WRE in October 1961 was that, for the first firing at least, Blue Streak should not fly as far as Talgarno but should be set to impact far short of it, at Dingo Claypan, only about 450 kilometres down-range not far from the old Emu atomic testing ground. Some of WRE's engineers feared that the engine cut-off system might not operate perfectly, so that an overshoot into the inhabited coastal strip near Port Hedland might occur if the engine did not cut off its thrust cleanly. However, RAE and De Havilland favoured an initial flight all the way to Talgarno. The total number of firings was going to be small, they argued, so all possible information should be extracted from each one. The longer flight with its greater acceleration would put revealing stresses on the rocket and its equipment. Eventually a compromise was reached. The planned impact point was drawn back a little to 1575 kilometres, putting a broad buffer 280 kilometres wide between the impact area and the coastal strip.

The three flights of phase 1 were followed by four firings with dummy upper stages in place with their tanks full of water and sodium dichromate solution (F4, F5, F6/1 and F6/2). These shots were all in a northerly direction in preparation for the first orbital shots into polar orbit. Two of them, F4 and F5, served as checks on the stability of the full Europa configuration. Two more, F6/1 and F6/2, had the second stages only live, in order to check its performance while carrying the dummy third stage. The third and final phase consisted of flights F7, F8 and F9 with all the stages live launched from Woomera between November 1968 and June 1970 (more than two years behind schedule) with a test satellite aboard to be injected into orbit with the assistance of a purpose-built tracking station at Gove in the Northern Territory. None of these last three firings was successful because of failures in the third stage.

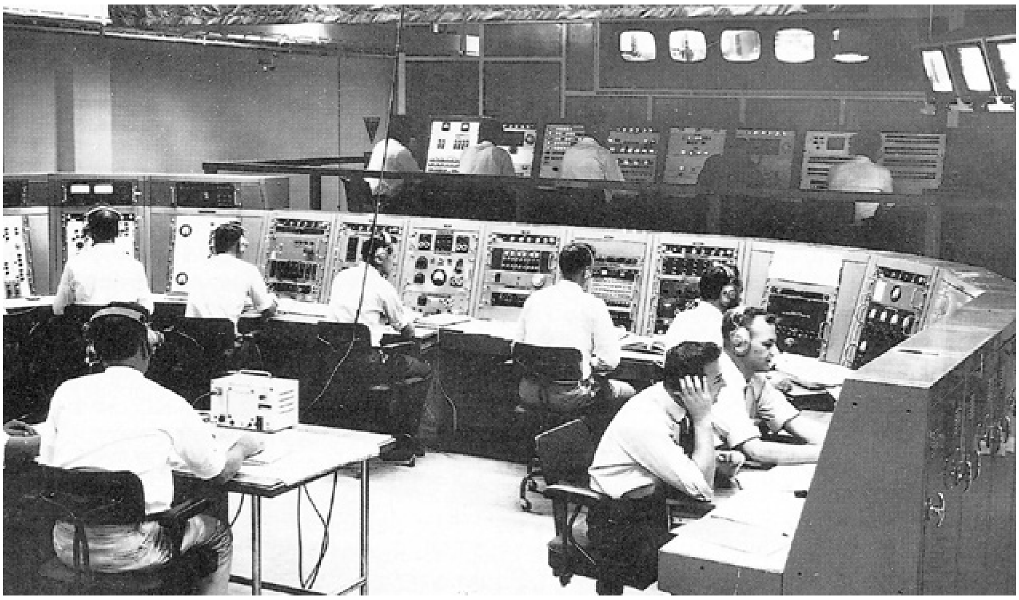
Each of ELDO's members was responsible for its own program, with the Secretariat having only a co-ordinating role. It was only at Woomera that the members brought together and integrated their separate endeavours. During phase 1 the Secretariat had much to do and found it both convenient and politic to leave the Blue Streak trials to the joint project partners while it concentrated on upper stage development. During phase 1 (1962-64), therefore, most of the responsibility fell to the teams from RAE and Hawker Siddeley Dynamics (which had absorbed De Havilland), with the ELDO Secretariat holding a watching brief. After the first trial in June 1964 the Secretariat appointed an ELDO representative in Australia, Colonel Jesse Dutton, a member of the Secretariat with previous joint project experience who held the position until ELDC) left. He had an office and staff of ten or so in the Contractors' Area at Salisbury, and his job was to keep the Secretariat informed and generally look after the ELDO teams at Woomera. Dutton was fond of representing ELDO in the media, which he had the right to do; but in the view of some WRE men he was rather too insistent about this right. They thought he made it rather too obvious that he regarded the Range staff as mere hewers of wood and drawers of water; and this perception, whether accurate or not, did not fail to cause friction from time to time.





Far right: Erecting the Blue Streak rocket F1 ready for final preparation, testing and launch. By then the tower had been raised ready for the three stage Europa I.

Right: Launch of F2, second Blue Streak to fly.



The Control room of Equipment Centre 6, nerve centre for the long countdown.

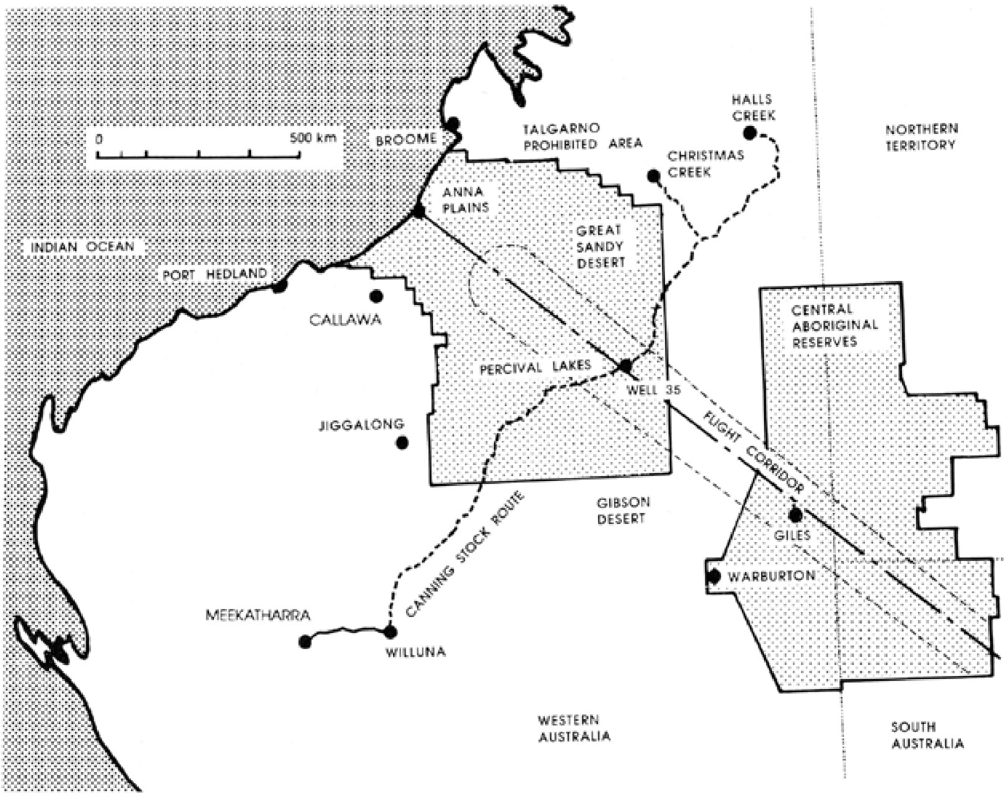
The F1 launch on 5 June 1964 was preceded by nearly six months' preparation after the rocket arrived at Port Adelaide on 18 January—not to mention many static firings at Spadeadam before it ever left Tilbury Docks. The Officer in Scientific Charge was Harold Robinson of RAE, who was to become the key British figure in ELDO. Even after the rocket was erected on the launcher, it stood for eighty-six days while the extremely elaborate preparations were made. The countdown itself took 48 hours and involved nearly eight thousand distinct operations by a large team of engineers. A strictly controlled sequence had to be followed, with every action listed on a document prepared by an IBM punched card system. On the day before a launch attempt the kerosene was loaded and then, about two hours before firing, the LOX; this operation took an hour. There seemed no end to the minor, vexing faults intrinsic to any large rocket launch where everything has to work with hairsbreadth precision. In the first five seconds after the instant of fire a whole string of electrical and mechanical events must happen right on cue before ignition is achieved and the thrust builds up to two-thirds of its full value. If for instance, a solenoid is slightly sticky and delays the opening of a valve by a few tenths of a second, the automatic sequencer will abort the whole attempt. With this degree of complexity within and outside the rocket, it is not surprising that there were endless postponements and delays. The weather was wrong, then a tiny slip ring failed in the yaw-roll gyroscope. One attempt got within four seconds of launch before trouble with the safety system caused an abort.

To the casual eye, Launcher 6A out at Lake Hart still looked much as it had done when first completed for the abandoned Blue Streak program four years before. A closer inspection, however, would have revealed one major difference. The original Blue Streak stood 21.3 metres high, whereas the complete three-stage Europa I was obviously going to be considerably higher. Just how much higher was not at first known: the first estimates, when the third stage and satellite carrier were still on the drawing board, ranged from 31 metres to 37 metres. The servicing tower built for Blue Streak was not tall enough, although it was known to be strong enough to allow the height to be raised by some 7 metres without much extra bracing. After considering various possibilities the engineers decided to raise the whole tower bodily off its travelling bogies and put extension pieces under each of the four main legs to give an increase of 6.65 metres. This exact measurement was chosen so that the doors, stairways and hinged floors could be recycled from the redundant Launcher 6B tower. It was the cheapest and easiest solution, since it could be done from the ground and need not disturb the existing installations too much. Raising the 500- tonne tower was no mean engineering feat. A 'Lift-Slab' jacking system was used, developed by the firm of Perini-Fricker. The method had been designed for building multi-storey offices and hotels: the concrete floors are poured at ground level and are then hoisted into position by hydraulic jacks in the columns. At Launcher 6A sixteen jacks were used, four on each leg. All were operated in unison automatically, and the actual rate of lift was about 50 centimetres an hour. When the job was done, the service tower was given ten levels to give access to each stage of the rocket.

There were other less striking modifications at 6A. The heavy launch platform or ring designed to support Blue Streak before firing, which incorporated quick release clamps to hold it down during engine light-up and thrust build-up, had to be reoriented to cater for firings to the north as well as the north-west. New fuel and oxidant filling, gas pressurisation, cooling air, electrical cabling and other systems were incorporated for upper stage purposes and terminated in flexible connections on a new umbilical mast straddling the original. This new mast was supported by a special outrigger structure and considerable juggling was needed to erect the new mast without disturbing the old one. The long time it took to fill the multi-staged Europa, demanded special modifications to the first stage fuelling system to enable it to cope with prolonged venting and topping up. New air-conditioning, breathing air and fuelling control and communication systems were also necessary.

Preparations of a different kind were going on far down-range. It was necessary to make a stringent aerial and ground search of the proposed impact zone in the Percival Lakes region, to ensure that it was quite vacant by the launch date. Despite a barrage of publicity, the search did not go smoothly. On 10 April 1964 WRE Director Bill Boswell learnt to his consternation that no fewer than forty or fifty men of an oil exploration company—West Australian Petroleum (WAPET)—had entered the Talgarno Prohibited Area and had built an airfield there, apparently with the concurrence of the Mines Department of the Western Australian government.[12] The latter was told in no uncertain terms that the WAPET team would have to be out of the area by 25 May, the scheduled firing date for FI. A security officer, Hec McDonald, was posted at the 'entrance' to the zone—the settlement of Callawa, north of Port Hedland—to inform the passing traffic of the trial and to ensure that the WAPET team moved out as instructed. McDonald had difficulties at Callawa. Both WAPET and its roadmaking team were inclined to ignore him, either because they had had no instructions from Perth or, more likely, because they had decided to turn a deaf ear. They treated McDonald like one of those soldiers who are found hiding in the jungle unaware that the war has ended long before. As far as they were concerned, all the prohibitions about Talgarno belonged to the earlier Blue Streak epoch. It was, they pointed out, 1964 now. All this talk about prohibited areas must be out of date. Anyway, even if a rocket was going to be fired at Woomera, what was that to them? Any fool knew that Woomera was far away across the country. So much for the ELDO publicity! Eventually WAPET's head office sent up an aircraft from Perth which took the men out at the last minute.[13] However, the WAPET airfield in the middle of the Great Sandy Desert was useful to the WRE search parties.

The sporadic presence of nomadic Aborigines in the Percival Lakes area posed another more delicate problem. The WA Commission for Native Welfare first advised that tracks



The impact zone in the Talgarno Prohibited Area, which had to be cleared of nomadic Aborigines and others for the three Phase 1 test flights of the Blue Streak first stage. (One of these fell short and landed near Giles.)

had been spotted there, but whether they were recent or not it could not say. In the desert such markings can last for years. With the launch date now approaching, better information was urgent; and so the ground search was put in the capable hands of Walter MacDougall, the Native Patrol Officer. With him were Terry Long and David Webster, two native welfare officers from Port Hedland, and Gordon McKay, an aged Aboriginal interpreter. MacDougall already knew that an air reconnaissance had sighted two campfires near the Percival Lakes, one of them within the impact area.

The logistics of these operations were fearsome. The vehicles carried only limited food and spares, and the successive postponements put extra strain on both man and machine. The country, 30 thousand square kilometres of red rolling sandhills, is some of the worst in Australia. Carnegie, an early explorer who dragged himself through it in 1896, described it as 'a vast howling wilderness of high spinifex- clad ridges so steep that often the camels had to crest them on their knees.' Even the four-wheel drives found the going rough and radio communications were so bad that on at least one occasion messages between the two ground parties had to be relayed via Woomera.

By 20 May MacDougall's party had made its way without incident to the southern side of the vast saltpan which is Lake Percival. That evening they saw smoke from five separate fires to the east, so MacDougall made camp knowing that he was in full view of the Aborigines on the other side of the lake. He did this deliberately, to prove that he was not trying to take them by surprise. But on the following day when the party followed very fresh tracks to a soakage nothing was found but three *pitdjis*, wooden dishes, and other signs of a panicky flight. No more campfires glimmered in the outback night after that. Low on fuel and by now outside the impact area, MacDougall made his way back to the WAPET airfield.

On 25 May came the news that the F1 firing had been postponed, and MacDougall took the opportunity to return to Lake Percival with his mechanic and Terry Long. He was concerned to find that the shy nomads who had eluded him before had now returned to a position just outside the impact area slightly north of their original camp site. Very aware that any further movement west or south might be hazardous for them, MacDougall took up a position at the 'gateway'.

After three days with the aerial search team, the other patrol officer, Bob Macaulay, had a four-wheel drive delivered to him by a Bristol transport so he could join the ground search. To Macaulay's disgust it was so poorly equipped that it did not even have a puncture

Alan Mole.

repair outfit![14] However, his party worked its way along the south side of Lake Percival until he met MacDougall, where he received the unwelcome news that the launch had again been postponed.

By 30 May, with the actual day of launch only six days away, the patrol officers had reluctantly conceded that making contact with the nomads was just not possible. In that forbidding terrain native bushcraft was more than a match for the technology of Europeans, even ones who could call for vehicle spares to be dropped from the sky by the RAAF. But Macaulay's final patrol on 4 June showed that the Aborigines had now drifted south to a position about 16 kilometres south of Lake Percival, well clear of the impact area.

After the anti-climax of FI's flight on the following day, when it fell far short of the impact zone, the NPOs started back for Giles. The experience had been frustrating, but at least they had prevented movements into the danger area. Even so, it appears that success fell short of their own expectations. MacDougall reported: 'Suffered mild shock on 6 June when we discovered that a party of at least four natives had camped at a point five or six miles west of Well 35 on the Canning Stock Route from 25 to 30 May'.[15] Though they may not have moved any further west into danger after 30 May, the fact was that the NPOs knew nothing of the group, nor had they been spotted during the air sweeps. The incident confirms that even men with a profound knowledge of tribal Aborigines can be deceived by their shy and elusive habits.

Back at Woomera, the day of success broke to a clear and chilly winter's morning. Few of the onlookers, probably, thought much of the rigorous precautions and sheer hard work that stood behind the coming fiery flight of Blue Streak. They were there for the spectacle. Hundreds of village people, including many schoolchildren who had been given a holiday for the occasion, were sightseeing from five miles away, rugged up against the cold, staring across the gibber plateau at the stumpy silver cylinder in the distance. Expectations were high, raised even higher by the unofficial race between Blue Streak and Bluebird; for Donald Campbell was then attempting to break the land speed record on Lake Eyre. Untimely rain made the saltpan dangerous and Campbell was forced to give up for a while, but for Blue Streak the moment of triumph had at last arrived. At five minutes, the final sequence began automatically and the final checks were made of the telemetry systems. At seven seconds the engines fired, quickly building to full thrust against the restraining jaws, which retracted at precisely zero. The 92-tonne bulk of the rocket raised itself from the pad with painful slowness. At this point it was expelling half a tonne of its mass every second, and it hardly seemed enough. Even as the spectators saw it begin to move, the PA system blared out: 'The vehicle has failed to leave the launcher'—a remark followed by a laconic 'I will retract that last sentence!' What had happened was that Alan Mole, a suave former Chief Petty Officer who had been roped in to do a commentary for the visitors, was too busy to glance out of the window and had been deceived by a light on a control board.[16] In fact the largest rocket ever launched outside the territories of the superpowers was on its way, about a decade after its conception. It climbed steadily above its brilliant orange exhaust and vanished into the northwest. Just a few minutes later it lay a mass of broken fragments in the desert.

The intervening flight may have been brief but thanks to the heavy instrumentation it had yielded a vast amount of information. Visual tracking up to 30 kilometres was by Askania and Contraves kinetheodolites and a battery of Vinten cine cameras. After that (with some overlap, of course) a radar system took over, with the ground stations at Red Lake and Mirikata locking on to signals from on-board transponders. These data were fed into impact predictors which computed in real time the expected impact point of the rocket. As in the case of Black Knight and all large rockets launched from Woomera, the Range safety officer used the data to trigger the WREBUS system, if required. In this first firing the aim was to obtain technical performance data, and three telemetry transmitters were carried, offering in all nine data channels. These channels were mechanically switched among about 300 different on-board sensors tapping sources of information about pressures, voltages, temperatures and so forth. All these were recorded on the ground on magnetic tape. In a flight lasting ten minutes, Blue Streak rose to a height of 170 kilometres and a speed of over 10 000 kilometres per hour. Most of the powered flight went according to plan, but the last six seconds were curtailed. As the tanks emptied the remaining propellants began to slosh about, causing oscillations to build up which the sensitive steering system could not cope with. Slow motion film taken through telescopic lenses showed the rocket rolling and then cartwheeling spectacularly across the sky before the engines cut out. The automatic break-up system triggered as the rocket slowed on entering the thicker levels of the atmosphere, and the remnants crashed to earth 1000 kilometres northwest of Woomera, far short of the Talgarno impact zone. The debris was scattered about the Aboriginal reserves, mostly to the east of the Giles meteorological station.

Fortunately F1 had fallen without mishap, but this could not be known immediately. At Woomera the impact into the reserves was taken very seriously, especially as it had happened without warning. Ironically enough, it had been the tiny risk of such an outcome that had caused WRE to argue for a Dingo Claypan impact, well short of the reserves. It had acceded to an overflight only because the probability of falling short was very low. But this was small comfort after the event. The question in everyone's mind was: Had any damage been done? An aircraft with a search-recovery team aboard left for Giles the same day, with instructions to locate the fragments at all costs. After two days of searching several pieces of the propellant tank's skin were found, not far from the junction of the South Australian, Western Australian and Northern Territory borders. The recovery team leader, Percy Hawkins, who had an uncanny instinct about such matters, was sure most of the wreckage must be about 120 kilometres northwest of Mt Davies, but by then it was too late to search further. MacDougall had already reported that no one in the Giles and Mt Davies area, Aboriginal or white, had been affected. However, three separate groups of bush travellers had witnessed the re-entry: the local mailman on his round, accompanied by an Aboriginal boy; a Western Australian government survey party; and a South Australian geological survey team led by the Minister for Mines, Sir Lyell McEwin. But none of them had seen anything on the ground. The trajectory records and the reports from the McEwin party suggested that the main impact area had been in the Murray Range, slightly south of and beyond the aircraft search area. Many years later this proved to be correct. In 1980 an expedition from Giles, tipped off by some Aboriginal children, found the debris in desolate country some way from the road about 60 kilometres south-south-east of Giles. They bore home an attractive piece of F1 to serve as an adornment to the mess at Giles.[17]

Despite this limited success, the launch of the first Blue Streak was a milestone. The British Minister of Aviation, Julian Amory, had the right to claim that the trial 'confirmed that Britain and Australia can meet their obligations under the first ELDO programme'.[18] At Woomera on the night of the firing the celebrations were riotous enough to be remembered years afterwards, and culminated with Boswell ceremoniously uncorking a jeroboam of champagne, the biggest bottle anyone had ever seen.

F2, the second trial in October, was wholly successful despite the many holds in the countdown. However, before F2 could lift off MacDougall had the vital task of determining whether the tribesmen who had eluded him in May and June were birds of passage or lived permanently around the lake. In the latter case, they had to be warned to stay clear of the danger area for the last two north-westerly firings of the program. MacDougall's efforts were not without drama.

On 2 September 1964 he left Woomera for Talgarno on patrol with a mechanic and a driver in another vehicle equipped as a workshop.[19] He reached Well 35 on the Canning Stock Route a fortnight later. Over the next few days he saw no Aborigines, although he noted that 'two of many pathways over Lake Percival seemed to have been used recently' and that 'permanent pathways on Lake Auld were seen.' After participating in an air search MacDougall went on to Jiggalong Mission where he engaged two young Aboriginal guides, Sailor and Njani. They moved out to Lake Percival where on 22 September he sighted smoke and on the next day saw fresh tracks along the eastern shore of the lake. He sent Sailor and Njani to follow the tracks on foot. They returned with a woman and a child, and as the party moved around the north-eastern end of the lake MacDougall found two more women and two children. Having fed them, and believing that they may lead him to the main party, Njani tracked the women and returned late on 24 September with an astonishing and pathetic group. The total number was now twenty: seven women, two adolescent girls, six male and five female children, the youngest about six months.[20] All were naked except for rough bark sandals, and their total possessions were some grinding stones, bowls and a single stone axe. One woman appeared to be leprous. MacDougall's log recorded laconically:

I fed them all. The story as I understand it is that the young men and big boys ran away. The men went after them leaving four men, one of them blind, to look after the women. Three of them died and the blind man, taking two wives, left the lake. He did not come back. He is supposed to be living north-west of the lake. The mother of the six months old baby says he was alive when she visited him approximately eighteen months ago.[21]

These people were in a serious plight. MacDougall himself couldn't do much to succour them. He had little food and his search was still incomplete. He set up camp and leaving his guides with instructions to dispense 'a piece of damper and a drink of tea each day' he patrolled eastwards for two days. Unfortunately, on return he skidded on the lake and smashed his rear differential not far from the camp. The workshop vehicle was dispatched to the airfield to fetch another, a round trip of 200 kilometres.

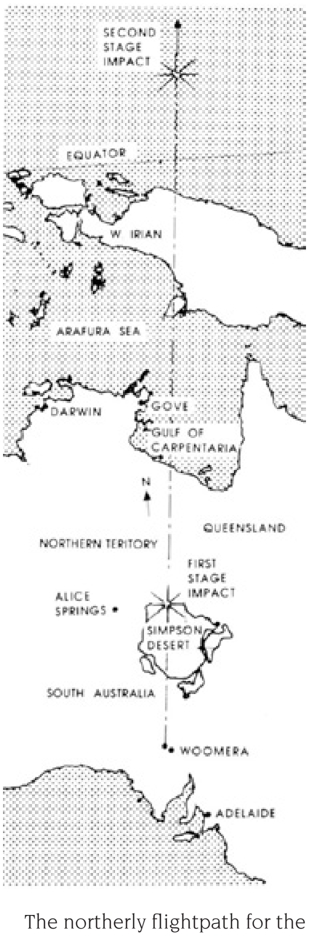
Meanwhile MacDougall's radio report of 24 September set in motion several actions. The Commission's Perth office was arranging a trip to the WAPET airfield for a specialist from the leprosarium at Derby, and the Port Hedland officer Terry Long prepared to join those in the field.

With a new differential in his 4WD MacDougall resumed his patrol, making a long careful search along the Canning Stock Route visiting all the wells from 33 to 40 without finding any signs of recent occupation. On 6 October he met Macaulay and two guides from Warburton Mission at Well 35. They decided that Macaulay should continue to check the area between Wells 35 and 31, and he departed taking all the guides and the workshop vehicle with him. Over the following week he completed this task without finding any signs of recent occupation, only to smash both differentials on a sandhill a few kilometres from Well 31.

Back at Lake Percival by now, MacDougall's vehicle had developed alarming new symptoms, and his food was low again. He radioed his predicament and Macaulay in the workshop vehicle went back to the airfield and helped to pack a 'storepedo' with food for MacDougall. A RAAF plane later dropped this over the lake and went on to do a final aerial check, signalling back 'all clear'.[22] Communications on 20 October—the eventual launch day—were difficult but MacDougall's party out on the lake were aware of F2's departure from Woomera. Ten minutes later, to everyone's excitement, they witnessed the re-entry.

Shortly afterwards ail the 'Eves without Adams', as MacDougall called them, were removed from the desert at their own request. The leprosy case was confirmed and the woman with her child was airlifted to the leprosarium at Derby. The remainder, plus another group of eight discovered by Macaulay's guides, set out for Jiggalong Mission led by Sailor and Njani, who in the meantime had married one of the Lake Percival girls.

The flight of F2 was uneventful. The sloshing problem had been cured and this time the engines burnt for the full period. The rocket lifted smoothly from its pad, climbed vertically, turned over to the correct angle of 30° from the horizontal and reached the right speed—about thirteen times the speed of sound—for the separation and launch of the second stage. The third flight on 22 March 1965 was equally successful and devoid of incident. In these last two trials Blue Streak covered the ground distance of 1500 kilometres and reached an apogee height of 240 kilometres, and in both cases impacted very close to the aiming point. The prelude to the northerly firings was over.

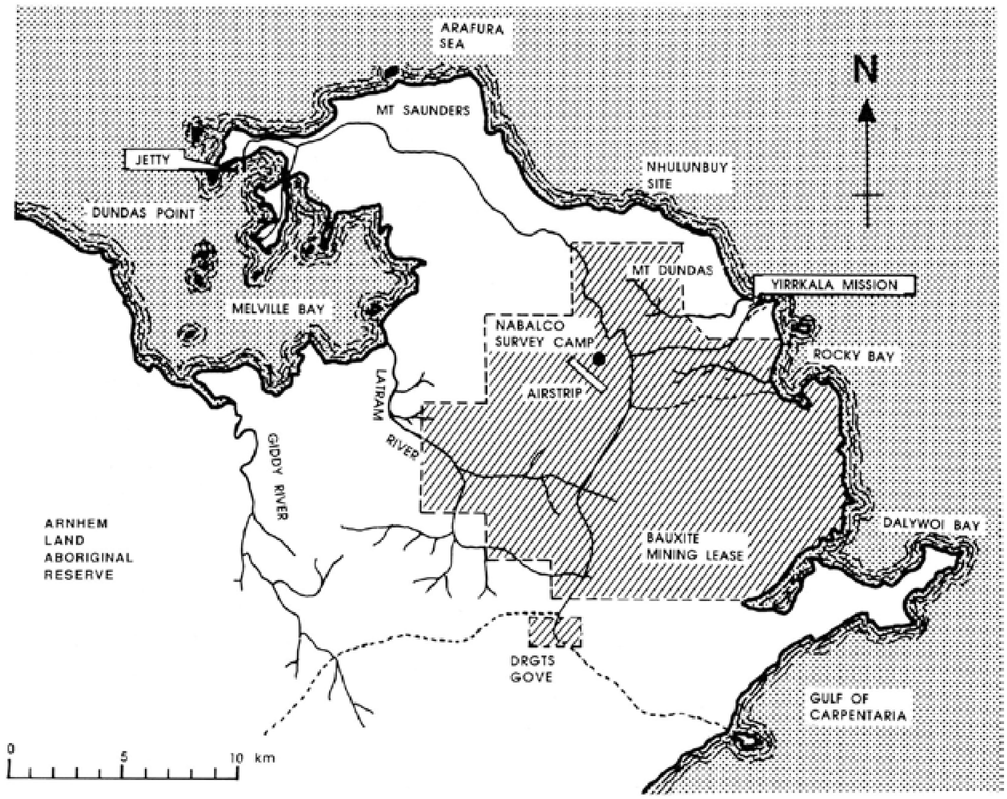


The northerly flightpath for the Phase II and III flights of Europa I. (The last three firings were intended to orbit test satellites but failed.)

THE DOWN-RANGE STATION AT GOVE

Early on in the planning of ELDO's Woomera program it had became apparent that a ground station would need to be set up far distant from the launcher, some two or three thousand kilometres to the north and within 450 kilometres of the line of fire. The purpose of this station was to provide the third stage of Europa with radio guidance in the last part of its flight. Had an inertial guidance system been installed in the stage a ground station could have been dispensed with, but this was never really feasible because of the extra weight and volume of the navigational equipment.

Selecting a suitable site and getting the work underway was given a high priority. WRE had come up with a northerly flight path running slightly east of north. It crossed into the Northern Territory and then ran almost parallel with the NT-Qld border, cutting the



Gove Peninsula on the NE tip of Arnhem Land, site of the 'Down Range Guidance and Telemetry Station' (DRGTS) used for the orbital attempts.

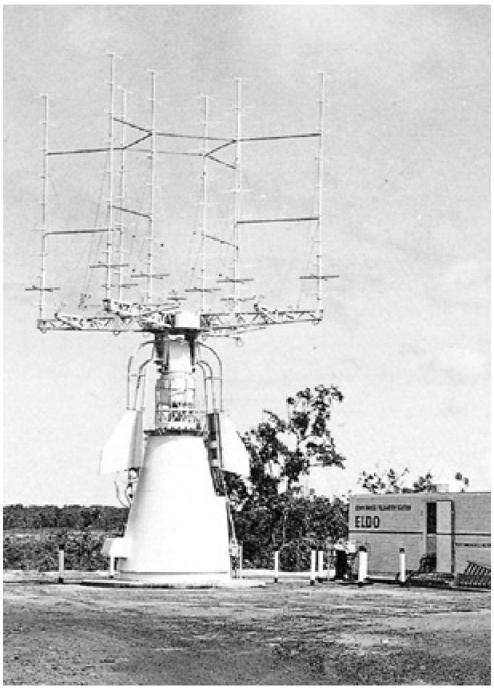
Australian coastline at the Gulf of Carpentaria and then heading out over the Arafura Sea and New Guinea. As soon as this was clear, an ELDO technical mission visited Salisbury in June 1963 for discussions on establishing a 'Down Range Guidance and Telemetry Station' (its formal title) on or near the Australian far northern mainland, ready for use when the first orbital flights became imminent. During this mission it was agreed that the Department of Supply would undertake the site construction and operation and that Australia would bear the full cost. The technical equipment then being developed was explained and detailed information was passed to Salisbury to assist in planning. Some possible sites were also considered: Cape Wessel, Gove Peninsula, Horn Island and Weipa, in that order of preference.

Gove on the extreme north-eastern tip of Arnhem Land was the final choice, after an analysis of the logistic problems, soil stability and other factors which took until the end of 1963. Though it is a very remote spot, Gove already had a good airstrip left over from the war and regular flights from Darwin to the Yirrkala Aboriginal settlement on the coast. The consortium of Nabalco was about to begin feasibility studies for bauxite mining, and the township of Nhulunbuy began to rise about the time that ELDO left.

WRE's Engineering Wing planned the Gove station and the Department of Works built it, starting in December 1964. Works had the station finished and ready for the equipment by November 1966. Staff had gone to Europe earlier in the year to gain familiarity with the hardware, and when it arrived specialists from Belgium, Holland, Italy and the Secretariat came with it to assist. Operation of the station was let out on contract to Hawker De Havilland Australia under manager 'Tubby' Vale and supervised by station directors Geoff Wood and (later) Vic Roberts. The staff of thirty-two was supplemented during launches by European representatives of the designing firms: MBLE and Bell Telephone of Belgium, Philips of Holland, and an Italian team which set up a satellite command station.

'Tubby' Vale, first manager of the Hawker de Havilland team that operated the DRGTS.

The station stood on a lonely elevated site on the edge of a bauxite plateau, from which the open sea of the Gulf of Carpentaria could be glimpsed about 8 kilometres away. It consisted of a living and support complex and three technical areas. The assumption had been that Gove would have a life of five to seven years, so most of the buildings were transportables. Existence in the living complex was comfortable enough. There was enough room for forty-eight single staff to work, sleep and eat, and plenty of recreational facilities: billiards, table tennis, a library and the usual run of indoor games. There was a bar, whose profits paid for an aboveground pool and a volleyball court, on which a station team



Right: The Dutch telemetry receiving station at Gove.

Far right: One of the dish antennas on its 'XY' tracking mount.

played Yirrkala Mission and Nabalco mining company geologists. Cricket was attempted but only two picnic matches took place before the ground was swallowed up by luxuriant tropical undergrowth. The staff also operated an amateur radio station (VK8UG), and on one occasion when the station's official radio telephone failed an amateur in Melbourne was contacted and persuaded to call Darwin to report the fault. Completing the complex was an administrative block, a few detached houses for married supervisors, workshops and stores. All the power was generated on site at both Australian and European standards and transmitted to the technical areas by underground cable. The bore water was ample, but had to be treated to be potable. Communication was by radio telephone and telegraph.

The technical areas were some distance from the living complex to avoid electrical interference, and each of the three served a separate purpose. The first was for guidance tracking, and consisted of five stubby parabolic dish antennas some 4 metres across mounted on massive servo-powered tracking mounts of the 'XY' type which allowed easy tracking of objects right overhead. Three vans full of computing and recording equipment and a building containing optical calibration equipment completed this area. The second was for receiving telemetry signals from the third stage, and was part of the Dutch contribution: it consisted of one multi-element antenna, a van of receiving and recording apparatus and a hut for the staff. The guidance and telecommand transmitting site included a sixth dish antenna similar to those at the tracking site, and an adjacent building housing transmitting equipment.

The system which would remotely control the orbital injection of the satellite was Belgium's contribution to ELDO. It functioned by locking electronically on to Europa's third stage and payload as this rose above the southern horizon at Gove, just four and a half minutes after lift-off from Woomera. As the powered segment of the flight came to an end, the system would track the stage, measure its position and velocity and dispatch to the controls on board instructions to move it to the best possible injection point in the minimum time. Finally, it would order the engine of the stage to shut down and the satellite to separate at the critical moment. The whole process was almost automatic. As it approached the point of orbital injection the third stage was travelling at about 8 kilometres a second. Before guidance commands could be issued, account had to be taken of parallax errors and distortion of the received signals caused by their bending as they came through the troposphere. Only a fast computer could handle these complex calculations and then issue the instructions in binary code interpretable by the pitch and yaw motors of the stage. The human operators had only to decide when the 1500 megahertz signal from the vehicle was sufficiently strong to start off the tracking and guidance sequence.

For Gove to play its proper part, it had to be able to make very precise, constantly updated measurements of the vehicle passing overhead. These measurements were made via the parabolic antennas arranged in the form of two interferometers. One of these had a base line between antennas of 16 metres, and measured the position of the stage. The other had a base line of 192 metres and determined its tangential velocity. In simple terms, each antenna of the interferometers received signals from the stage's radio transmitter at slightly different times and therefore slightly out of phase. Providing the length of the base line between the antennas was known exactly, the computer could calculate the relevant angles. Another array measured the precise distance of the stage by radar and the two measurements together gave the position and the velocity of the transmitter. Very full precautions were taken to ensure that the base line distance did not alter. The antennas were mounted on concrete foundations sunk 8 metres into the ground, and in the case of the short based interferometer the two foundations were physically joined below with heavy beams. By using precision measuring instruments and built-in adjusters, the distance between the antennas could be fixed to better than one fifth of a millimetre. With these refinements the accuracy of the Gove tracking system was remarkable: it could determine the position of an object 560 kilometres above the earth within 15 metres. To do this successfully, though, it had to be recalibrated regularly by optical means. A Canberra aircraft equipped with a high intensity flashing light and a transponder as used in Europa's third stage was flown over the station at an altitude of 12 kilometres on a clear and moonless night. On the ground an array of precision fixed ballistic cameras, the same as those used at Woomera for certain night trials, took photographs on old fashioned glass plates of the flashes and the star background as well. Later, the plates were read carefully at Salisbury using the star background as a precise frame of reference. By this means the position of the flashes could be fixed by triangulation with an error of no more than 24 millimetres.

During the trials Gove was prepared in unison with the Europa at Lake Hart thousands of kilometres to the south, using duplex telegraph and voice communication links. During the final moments of countdown the launch sequence time and the precise instant of lift-off were crucial data, and to reduce the risk of failure just then all telegraph traffic generated by the Range was looped back to Woomera from Gove as an assurance that the transmit and receive circuits were both working. After the satellite had been injected into orbit, the telegraph circuit could be extended via Woomera to Bretigny near Paris, which was the centre of Europe's worldwide network of satellite tracking stations.

Normally the station worked a sedate six-day week, although at launching times everyone moved on to fairly gruelling shifts. Since teamwork and dedication to the job were essential, all the staff at Gove were vetted for psychological stability and the ability to work under pressure in a small and isolated group. For, of course, the station was very isolated; so isolated that herds of buffalo sometimes wandered through it, creating a hazard for drivers and pedestrians at night. Bauxite mining was on the horizon but had not yet begun. The nearest qualified medical help, for instance, was a nursing sister at Yirrkala, 30 kilometres away. A medical team visited the Gove area every month and for minor cases and emergencies there was a kit of numbered prescriptions to be used on radioed instructions from doctors in Darwin. Though Gove was readily accessible by sea and air, it was not so by land: it is said that during the three years of operation no more than six four-wheel drive vehicles completed the 450 kilometre trip east from Katherine. The staff came and went by air on leave, as did special shipments. General supplies came by sea: ocean-going barges operated to various Aboriginal missions as far east as Groote Eylandt, and the A*lagna*, a supply ship from Brisbane, provided a regular monthly commercial service. Both were used, but the ship was the principal lifeline, unloading foodstuffs, refrigerated cargo and fuel on to a jetty at Melville Bay, 40 kilometres of dirt road from the station. Leave entitlements for the staff were liberal and the commercial air service was much used for that purpose and official business. Europeans visiting the station normally arrived in Darwin and then flew on to Gove by DC-3, landing on rough mission airstrips en route. Many found this a unique experience. Most people, in fact, found their lives full of interest. Sunday was a day for relaxation. Two aluminium boats and some private craft were available and were much in demand for exploring and fishing from one of the many beaches which had scarcely, if ever, felt the impress of a white foot. Sharks, stinging jellyfish and the sight of an occasional crocodile dampened the ardour of swimmers, but the fishing was superb: barracuda and cod were the chief sport and parties often returned with a catch of twenty more than a metre long. Oysters could be gathered in quantity at low tide. Barbecues and picnic lunches, followed in the evenings by games of Scrabble in four languages, were popular recreations. And then visitors were always arriving. The gradual easing of entry requirements by the NT Administration meant more casual travellers through Arnhem Land, and some of these found their way to the station. Many official parties were welcomed too: doctors and dentists, policemen, politicians, Rolf Harris and his family, and a ministerial party which included Mrs Gorton, wife of the Prime Minister. No women's facilities existed at the station, and she and her companions were obliged to use the men's. Despite the care that was taken with the scheduling, an innocent staff member suddenly found himself in unexpected company. A notice proclaiming 'Bettina Gorton showered here' was later fixed to a cubicle to mark the event.

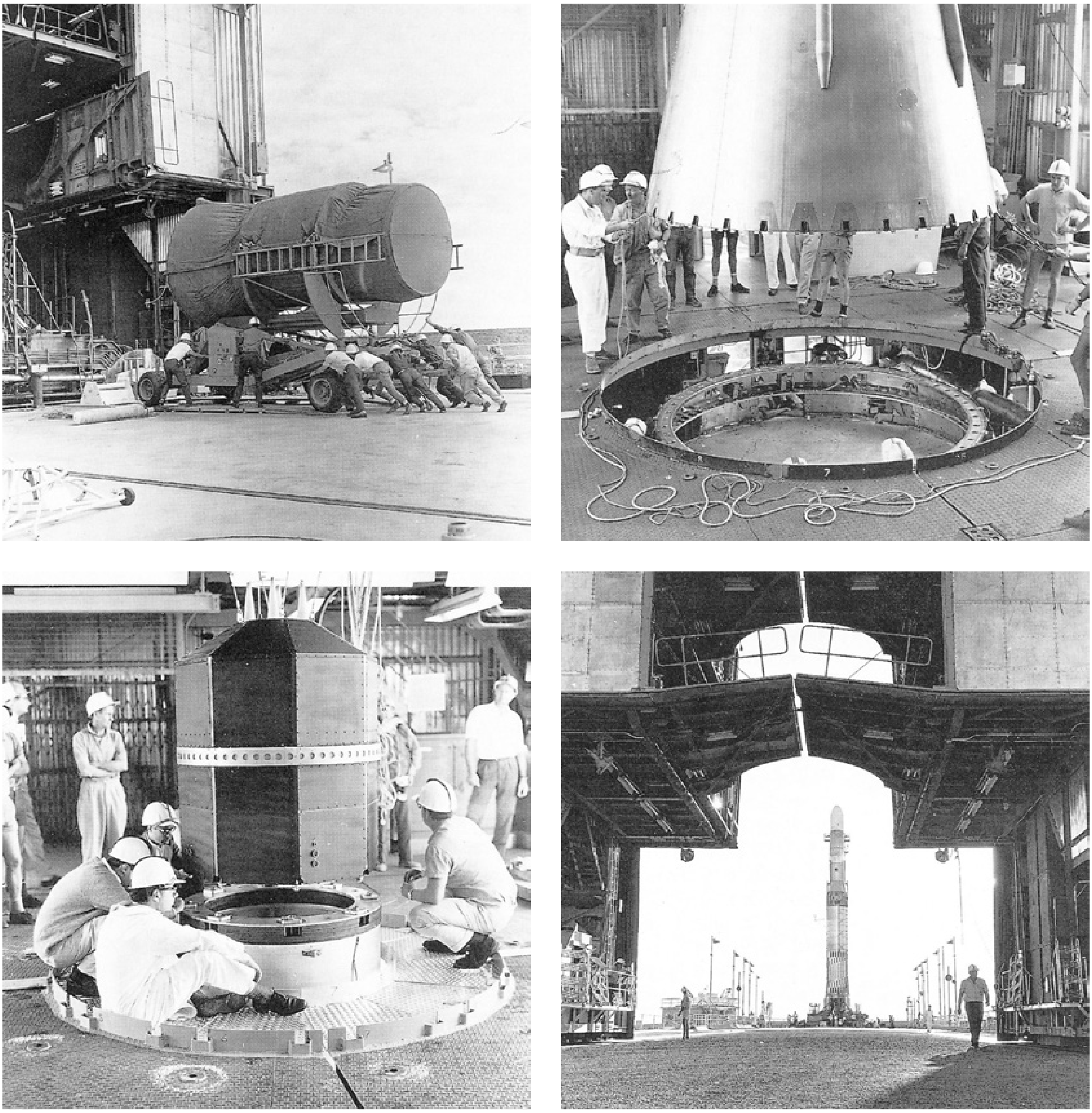
Relations with Yirrkala mission were uniformly excellent. Though entry to the surrounding reserve was discouraged, some Aborigines were employed at the station as cleaners, groundsmen and kitchen hands. They and some of the elders of the Yirrkala community were always eager to show their skill with the spear and to teach some of their bush lore and crafts, and many bark paintings depicting local legends were commissioned by the staff and visitors. To his great embarrassment the bald Belgian Henri Vigneron was given an ecstatic welcome by the Yirrkala elders. They thought he must be a consummate artist, since their people used tufts of human hair as paint brushes. All who lived at Gove station have many such memories to cherish, and believe they were richer for the experience.

THE TRIALS OF EUROPA: THE LATER PHASES

The establishment of Gove made a northerly flight path technically possible, but dealing with the safety and public relations angles required considerable diplomacy on the part of WRE. Here, after all, was something quite new. For the first time in the history of Woomera, rockets would be transgressing the normally inviolate Range boundaries and overflying a great span not only of the Australian mainland but of foreign territory too; and the first and second stage remnants would be falling to earth outside of the proclaimed prohibited areas. Each of these factors presented special problems, and it took the six years 1960-66 to resolve them fully.

In point of fact, to fire northwards into orbit was not the only option. Only easterly firings were entirely ruled out because of the population densities along the east coast. But firing south-west was one possibility, down into the Antarctic Ocean. Here there was plenty of space, and both the first and second stages could fall into the sea. North-west along the centre line was also possible, of course; in which case Talgarno could provide an impact area for the first stage. But both these routings had their problems. Any firing to the south meant a guidance station would have to be set up in a very remote area; and firing to the north-west meant fighting against the potential catapult advantage of the earth's rotation eastwards.

The northerly route was therefore the most practicable one. It also suited ELDO, whose requirement was for a polar or near-polar orbit. The main problem with this route was choosing an impact zone for the first stage. The technically ideal distance would be some 1300 kilometres from Woomera, but that put the zone in relatively settled country. The problem was not the overall density of population, but the fact that it was concentrated in a number of settlements and homesteads. The risks were judged unacceptable. The first stage had to be made either to fail 'short' into the Simpson Desert, whose northern limit lay some 795 kilometres from Woomera, or 'long' into the Gulf of Carpentaria, and it was up to the vehicle designers to keep this in mind. Eventually the sea impact zone was ruled out on the grounds that it would strain the performance of Blue Streak to the limit and certainly would not allow the payload size to be increased in the future. The Simpson Desert impact zone had a cost too, because the Blue Streak would be jettisoned before delivering its full performance, but it was a cost which had to be borne. The next step was to speak with the pastoralists whose properties lay within the huge safety area which surrounded the uninhabited impact zone. (There were no Aboriginal settlements anywhere in this region.) Securing this co-operation was critical to the plan, for it is unlikely that anything could have been done without their permission. Europa I was a civilian project, and there could be no question of gazetting another prohibited area.



On 6 March 1966 a WRE team set out for Alice Springs and were joined there by various Northern Territory officials: from the police, native welfare, the pastoral inspectorate and the Commonwealth Department of Works. Over the next few days they flew to nine homesteads. Everything went very smoothly. Thanks to the bush telegraph, news of the mission preceded its arrival at each point, and most of the pastoralists were very interested to hear of what was being planned at Woomera. The news that the actual impact zone of the first stage was uninhabited put everyone at ease very early in the proceedings. Eventually twenty-one new shelters were built to cover the dispersed population on twelve stations, the homesteads of which were given radiotelephones to give them a direct link with Woomera.

Erecting the upper stages of F4—*Top Left*: The French team wheels up their second stage. *Top right*: . . . and mates it to the Blue Streak first stage. *Bottom left*: Mating the Italian dummy satellite to the German third stage. *Bottom right*: Finally the gantry is wheeled away to reveal the complete Europa I. (J. G. Gale)

F4, launched one day behind schedule on 24 May 1966, was the first to use Europa in its complete configuration and an impressive sight it made at Lake Hart. All seven national teams helped to prepare it, although the second and the third stages were dummies and did not separate from the Blue Streak carrying them. The atmosphere of this trial and indeed of others in the series is well captured in a briefing for the media just before launch by the Principal Officer Ranges, whose job it was to ensure that the complex of recording and controlling systems were ready to merge with the vehicle systems for the firing:

> The brief and vivid drama which will hold our attention this morning is the climax of weeks of steady work and co-operation between the seven national vehicle preparation teams, and between the integrated ELDO range user team and the Woomera range.
>
> The range equipment activated for this trial is spread over an area which is about 120 miles long by 50 miles wide. Within this area are many small isolated recording posts as well as the more massive equipments contained in the vicinity of the rangehead itself and at other major instrumentation centres. At all of these places, staffs of operators, technicians and others have been working through the dark hours of the night checking out and setting up recording, safety and monitoring systems for this morning's trial. All positions about the range are linked by an extensive intercom network and over this a busy hum of activity spills out from the major centres to the quietness of the more lonely outposts. At this time the intercom traffic is approaching a minimum as all posts have completed their preparations. The cameras and tape recorders are loaded and ready, the plotting tables and radars are manned and set up, the telemetry receivers are awaiting flight signals from the array of aerial mounts which quiescently point towards the ELDO launcher, and the complex trials organisation of the range is poised to meet its commitment.[23]


Geoff Wheaton

Things did not go quite as calmly on the 23rd as this description suggests. At first F4's autopilot had a fault and then there was trouble in the safety tracking/ prediction system. By the time this had been rectified it was 10.30 a.m. and the sun had risen sufficiently to interfere with the optical tracking. It meant a 24-hour postponement. Early the following morning preparations went forward smoothly until half an hour before launch. Then a sensor detected that the LOX level in the first stage tank was falling. A quick investigation by the Australian National Team diagnosed the fault as being in the LOX dumping system which was not on the rocket itself but among the machinery of the emplacement on which it was standing. A valve was stuck partly open. If a small plug nearby could be removed the valve would close and the launch could proceed. After some discussion the Team Leader, Geoff Wheaton, moved into the open and approached the rocket on foot. As he moved closer along the causeway the tall Europa on its pad jutting over the lakebed towered like a shiny obelisk high above his head. Jetting from a relief outlet low on its flank was a plume of LOX vapour. It was a quite unnecessary reminder that inside the frail metal skin of the first stage, immediately above him, were a hundred tonnes of liquid oxygen and kerosene, awaiting their fiery union in the combustion chambers. Wheaton pulled the plug, and withdrew. F4 lifted off perfectly at 9.06 a.m.

To the assembled media Wheaton's action looked like one of mad courage and they wrote it up dramatically as 'an act of extreme heroism'. Wheaton himself scoffed at this, saying afterwards that if there had been the slightest danger he would not have gone anywhere near the emplacement. Yet, while his rational mind told him that the complex safety interlocks made the Europa safer than a fully fuelled Jumbo jet on the runway, his skin must surely have crawled with the realisation that he was the only human in the open for miles around.

F4's problems were still not over. Its flight was abruptly curtailed in an incident which produced a great deal of bad feeling and recrimination between some of the ELDO people and WRE staff, including a monumental row outside Woomera airport. One hundred and thirty-five seconds into the flight data from the Red Lake radar station suggested that the rocket had abruptly turned to port. Over a span of a few seconds, the plot moved quickly towards the lefthand cut-down boundary of the flight path and very nearly reached it though it did not cross it. Flight Safety Officer Jack Evans manually triggered WREBUS and the rocket was destroyed, the remnants crashing in the southern Simpson Desert. As the destruct signal was sent the plot started to return, indicating normal flight. The postmortem which followed in Paris and at Salisbury revealed a number of contributory causes on the part of both vehicle and Range, the main being the type and location of the radar transponder aerials on the rocket itself, coupled with a slightly premature reaction from the Flight Safety Officer. Various remedies, including modifying the aerial and widening the flight corridor substantially, prevented the situation arising again.

The following launch F5, where the upper stages were still dummies but did separate from the first stage, was successful despite suffering one particularly frustrating abort on 14 February 1967. The countdown got within ten seconds of ignition before a frantic voice over the PA system ordered 'Stop, stop, stop, telemetry stop!' producing a loud groan from the forty or so assembled media people. The fault was in the control panel of a telemetry aerial array. The next morning, however, all went well. This Europa reached a height of over 100 kilometres and the remnants fell into the Simpson Desert south-east of Alice Springs.

The two F6 launches had a live second stage, but the third stage was inert and the STV was a basic package consisting of a beacon and telemetry. The launch of F6/1 was subject to a maddening series of eight aborts over sixteen days. It did not lift off until 4 August 1967, in a last attempt which one man at centre stage recalls as verging on the desperate.[24] The weather was deteriorating again, and the windspeed limit had already been relaxed once. Some of the Europa's components had by that time far exceeded their planned working life. For instance, the oxidant liquids used in the upper stages were extremely corrosive, and after some days began to attack the pneumatic valves and the lining of the tank: just one more abort and the second stage would certainly have been disassembled and returned to France. Probably no one was terribly surprised, then, when the Coralie stage did fail: its engine did not light up. F6/2 was a repeat run except that the separation of the inert third stage was to be tested. Unfortunately this time Coralie failed to separate. After careful analysis of the records it was decided to go ahead with phase 3, where the third stage would be live too, notwithstanding the failings of Coralie. This proved to be the correct decision, for the second stage did indeed perform properly during F7, F8 and F9.

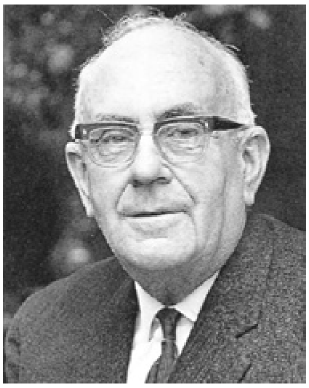
Europa's troubles now shifted up to the German third stage. At the F7 launch, on 30 November 1968, this stage burnt only for seven seconds and then cut out and exploded. The reason was that an explosive bolt, part of the safety system, had inadvertently been triggered by a stray electrical current and had perforated the diaphragm separating the fuel and the oxidant. The tank, piping and circuitry were heavily modified, but to everyone's horror the stage failed again in just the same way at the F8 launch in July 1969. This meant, of course, that the Italian satellite did not achieve orbit on either occasion, although the ELDO authorities refused to concede afterwards that this had been the primary purpose of the two trials. After F8 the design of the third stage was grimly reviewed right down to the last nut and bolt by two separate teams. More than a hundred engineers were involved from twenty aerospace companies, many from outside ELDO.

Naturally the hope was that it would be third time lucky with the last chance at Woomera, F9. Certainly ELDO badly needed a success. Tension was heightened by a cancellation due to a failure in the impact predictor and a postponement for twenty-four hours, followed by another the next morning. But when F9 was finally launched, at 10.40 a.m. on the morning of 12 June 1970, it was a fiasco. Though officially designated another 'partially successful' trial this anodyne phrase could not disguise the fact that the heat shield around the satellite had failed to eject and the satellite had fallen into the sea off the Antilles.

During the last disappointing phases of the program in 1969 and 1970, the Australian media, formerly so enthusiastic about the presence of ELDO, became very rude and impatient about it. Indeed, among the science journalists, who for eight years were automatically invited to each launch and who most understood what was going on, Europa became something of a laughing-stock. They grew very tired of the flights up from Adelaide in the middle of the night, which more often than not were succeeded by a sleepily irritable return trip a few hours later after yet another abort. One journalist reported with feeling that, having once regarded Europa as a magnificent symbol of the Space Age, he now loathed the very sight of it apparently glued immovably to its launcher. Michael Daley of the ABC and the *Advertiser's* Barry Hailstone founded a club, the 'National Association of Science Writers Yet To See an ELDO Rocket Fired Successfully', for which the spoof requirements of membership were that a writer must have travelled further trying to catch a successful launch than the distance a Europa would travel putting a satellite into orbit. The first successful injection would be the occasion of the club's dissolution. There was an even more scandalous if temporary 'Mickey Mouse Club' made up of some of the Press contingent flying up and down to Woomera. They threatened to wear suitable ears on the plane for the next trial, whereupon the invitations they had formerly received as a matter of course suddenly stopped arriving.[25]

ELDO LEAVES WOOMERA

It had been clear from the beginning that the project's services to ELDO at Woomera would at least be curtailed after Europa I. At the conference in Paris as early as April 1966 it had become evident that interest now centred almost exclusively on geosynchronous satellites for telecommunications purposes. The determination now was to move to a more powerful version of Europa (sometimes called 'ELDO-B') by adding two extra stages, including one in the payload, so that it could manage to launch satellites of a tonne or more into stationary orbit. The French were so keen on this idea that for a while they seriously proposed scrapping the current program to release the required funds. A geosynchronous satellite is, by definition, one that is travelling eastwards at the same angular speed as the Earth's rotation, at 35 880 kilometres above the equator. Woomera is at too low a latitude for injecting a satellite into an equatorial orbit without a difficult dogleg manoeuvre, and launches over the populous east coast were probably out of the question. Woomera could have no permanent future as an orbital launching site, and ELDO's move from it became more and more a certainty as the 1960s wore on. The French choice was Kourou, the elaborate range they were building about 50 kilometres from the town of Cayenne in Guiana, on the eastern coast of South America. Under the control of their research and development agency, Centre Nationale d'Etudes Spatiales, Kourou was an extremely favourable site within a few degrees of the equator and with unimpeded access for firings to the east to take advantage of the earth's rotation; it had clear access to the north and south for polar firings too. The ministerial conference in Paris in April 1966 addressed itself to the problem of the inevitable move. One possibility was to use San Marco, the Italians' audacious mobile seagoing launching platform which consisted of two converted oil rigs joined by submarine cables able to be towed into suitable equatorial waters, say off the coast of Kenya.



Senator Denham Henty, Minister for Supply 1966-68. He fought unsuccessfully for an equatorial launching site near Darwin. (PA)

Another possible choice, a good one on the face of it, was the town of Darwin, roughly in the middle of Australia's northern coastline. At the conference Senator Henty, leader of the Australian delegation, put up a spirited case for a launching site just outside Darwin. He was well primed by a lengthy project study commissioned by ELDO and written by WRE.[26] Compared with Kourou, he said, Darwin could have much better operational support from Adelaide and the climate was less taxing. The town was growing rapidly and being an administrative centre had excellent resources and a trained labour force. Electronic communications were good and Darwin already had a direct daily air link with Europe. And most importantly, of course, Darwin was accessible by road from Woomera, with its superb resources. If it were chosen, said Henty, Australia as a continuing member of ELDO would pay for everything necessary there, including the land, services, communications and housing. This offer was a remarkably generous one, for the value of these facilities would assuredly have been a great deal more than a contribution to the revised ELDO program based on Australia's GNP. Altogether the technical and economic case for Darwin was persuasive—provided the politics were left out. But the French in particular were adamant about Kourou, not least because they were committed under the Evian Treaty of July 1967 to evacuating their Sahara site and handing it over to their ex-colony Algeria. In any case, France was now paying the piper the most and naturally insisted on calling the tune; indeed, an undercurrent to the discussions was the unspoken threat that it would pull out of ELDO unless Kourou was agreed to. Darwin was never really in the running, and with its rejection went Australia's last hope of acquiring an international space facility on its own soil. The cancellation of Britain's own Black Arrow in 1971 after the successful launch of the Prospero satellite heavily underlined the point.

ELDO made an orderly exit from Woomera, as the decision taken at the 1966 conference to leave at the end of the initial program gave ample time to prepare. But WRE was still left with a great deal to do. The Commonwealth wanted to sell off all the surplus equipment using the disposals system, but the ELDO rules provided for a first refusal by member states. This meant that a number of bureaucracies had to be consulted before any item was sent to public auction. It was not the way to get things done quickly. The physical task of removing equipment was also a large one, especially in the case of the tracking station at Gove. It belonged entirely to ELDO and being so remote most of its staff would quite likely wish to leave before it closed down. A bonus payment to the staff if they remained until the end did act as an inducement, and in the event it all worked out quite neatly. After F9 was fired in June 1970 Gove's only remaining task was to track the Black Arrow launch of September 1970, when a 30 centimetre satellite called Orba was to be injected into an elliptical polar orbit. It was fired on 2 September, but as described in detail later the second stage failed to supply sufficient thrust and Gove could do nothing but track it until it fell into the sea north of New Guinea. After this seventh and rather dispiriting assignment the thirty-five members of the Gove staff began to leave. Some of the technical equipment was returned to Europe, some of the tracking antennas were acquired by Engineering Wing at WRE and Telecom for communications purposes and the telemetry equipment was sold to the Indian government for use on its rocket range at Trivandrum in Travancore State. Other miscellaneous equipment to the value of about $45 000 was auctioned locally, and ELDO finally vacated the Gove site at the end of 1970. About twelve ELDO employees remained when the Northern Territory administration took over in November. Over the next year the buildings were refurbished for the use of Dhupuma College, a residential transitional school for the Aboriginal teenagers of eastern Arnhem Land. The buildings began to deteriorate quickly over the next few years and a plan to give the College permanent buildings was not proceeded with, allegedly for economic reasons: the student numbers rarely exceeded forty and each place was costing $12 000 a year. After a good deal of indecision the College closed in August 1980 at very short notice. Eventually some of the more useful buildings were moved to Nhulunbuy where the dining rooms, for example, became the clubhouse of the Gove Yacht Club. The squalid remnants were still littering the site in 1988; a mess that no one, apparently, is responsible for cleaning up.[27]

At Woomera and Salisbury, the task of closure was more complex but not quite so urgent. The joint project acquired the ELDO mess and the housing in the village and Test Shop 10 went to the Commonwealth. A lot of equipment went back to Europe or to Kourou; much was purchased by government agencies and the remainder was declared surplus. Only a few items on the asset list had finally to be explained away. The more resourceful scrap merchants did very well. One particular case involved the underground cabling at Area 6, which WRE advised should be abandoned as it would cost more to remove than the copper was worth. Colonel Dutton, the ELDO Representative, persevered and finally found a contractor who took on the job using removal methods that were highly unusual but also profitable. The ELDO Management Group at WRE was disbanded in mid-July 1971 and the Representative farewelled by WRE on 23 July 1973.

Toppling the Area 6 gantry tower prior to cutting it up for scrap.

In the meantime Europa—in Greek mythology she was the daughter of Phoenix, ravished across the sea by an amorous Zeus disguised as a bull—had been carried off across the Pacific to Kourou. Here the plan was to use six more Blue Streaks up to 1977: two in

The Blue Streak chicken coop in South America. (Keith Grant) development firings at Kourou, two more to orbit the Franco-German Symphonie satellite, and two more for scientific satellite launchings on behalf of ESRO. On the first launch of the Europa II program, on 5 November 1971, the rocket exploded before the second stage could separate. The next month Britain withdrew from membership, having been offered the chance to join the American Space Shuttle program. The end finally came on 29 April 1973 when France and West Germany, now the principal contributors, told the Council that they would cease to fund Europa I on 1 May 1973. After nine years of effort ELDO formally closed its launcher program. It sold off the last of the Blue Streaks to a farmer outside Kourou on whose property it rests to this day, serving the humble but more enduring purpose of a chicken coop.[28] The expenditure of $A620 million and nine years of effort had not sufficed to place even one satellite into orbit.

ELDO IN AUSTRALIA: WHAT WERE THE LESSONS?

For all its failings, which were undoubtedly many and grievous, the work undertaken by ELDO using the joint project facilities in Australia was impressive, and the idealism that stood behind it was certainly praiseworthy. That such an enterprise could be proposed and agreed to at all marked a heartening step along the painful road to European unity. Effective long range rocketry had been the child of war in the Western European theatre. Less than twenty years earlier, many citizens of two of the ELDO partners—Britain and Belgium—had died under the guided missile bombardments of a third partner. Now here the ex-combatants were in the Australian desert, co-operating in the development of a new rocket in strict lineal descent from the old V2, entirely for the betterment of mankind. This was a fine thing, although of course ELDO was only one small marker of growing European unity. Then again, technically the ELDO program was the most spectacular and the most complex activity ever undertaken at Woomera. It brought a new sense of purpose and a new meaning to the joint project at a low moment in its fortunes, and the effect on the village was wholly good if not very lasting. Yet the fact remains that, measured against its ambitions ELDO's achievements were insubstantial.

What, then, went wrong? Certainly ELDO was beset with problems of costs and time from the start. These are familiar problems when working at the edge of a technology, but they were inflamed in ELDO's case by the determination to spend as little money as possible. As the magisterial journal Nature put it in an editorial under the title of 'One White Elephant', 'the problems of ELDO have sprung from trying to accomplish in five years, and with small resources, developments which have taken three times as long, and which have cost enormous efforts elsewhere.'[29] Some problems were intrinsic to the way ELDO was set up. The volatile nature of some of the members' governments meant delays every time a policy decision was called for. The ELDO bureaucracy itself was appallingly cumbersome, generating mountains of paperwork. For each trial Missile Projects Group at Salisbury had to prepare all the documentation, which, with the wide distribution demanded, might amount to thousands of pages. These documents often had to be emended back at Salisbury while operations were in progress, a source of huge irritation at the Range. The maze of committees which had to be negotiated before the slightest change to the vehicle could be made not only slowed progress generally but stifled initiative: it made the engineers chary of suggesting modifications when they knew full well that the immediate effect would be a long delay until a decision filtered through.

Then there was the problem of international co-operation. The cruellest critics of ELDO said that a better name for Europa would have been Chimaera, the fabulous monster with a lion's head, a goat's body, and a dragon's tail, whose name also means an illusory fancy, a wild and incongruous scheme, or an absurd medley of parts. ELDO was not a wild scheme, nor were its objectives absurd; but its architects seriously underestimated the problems of running a rocket project involving several nations with five languages, all with their own priorities and political ambitions and different senses of commitment. National rivalries were never far below the surface in a situation where people with deep-rooted traditional animosities were working together, and there were great opportunities for recrimination when one nation was so embarrassingly identified with the fortunes of individual stages of the rocket. When the first phase of the program was such an unqualified success (which it certainly should have been given the resources and the inordinate development time enjoyed by Blue Streak) great pressure was put on the French and German teams. They were in -the unenviable position of having to start from scratch and perform to a very tight timescale, in fields of quite advanced technology. Unfortunately the odds were against them, yet naturally they were reluctant to lose face by admitting that the taxing schedules were unrealistic.

One charge in which there was little substance was that ELDO was blasted at the root when Britain tried to find a use for something obsolete: a military rocket that ought never to have been patched to the purpose of a multi-stage rocket. 'Europa', these critics said, 'was designed around a surplus ballistic missile because it happened to be there.'[30] But as we have seen, the concept was worked out on paper long before Blue Streak became redundant. Technically there was nothing wrong with the decision to adopt Blue Streak as a first stage. Such boosters are enormously expensive items of hardware. Since all else depends on their performance they must be as reliable as human ingenuity can make them, and it is good engineering practice in such circumstances to be conservative: to do as nature does and adapt the old to the new, to go for evolution rather than creation. The flawless performance of the first stage throughout its career at Woomera, and the repeated problems with the new upper stages, shows the wisdom of this approach. Indeed, in retrospect we can see that the moment of decision for ELDO came as early as March 1965 with the success of F3, the last of the Blue Streak proving flights. An unbroken run of success had taken morale to its peak. Nor had these first stage tests suffered a great time slippage: the program had been completed within four months of the target date set back in 1962. If the member states had been really in earnest about achieving a useful satellite launcher at all costs, now was the time for a big push. The form this had to take was obvious enough. Adequate funds had to be forthcoming for a second ELDO program at an equatorial site where high energy upper stages could be developed to put a heavy payload into geosynchronous orbit. It would have been expensive, no doubt of that, and the costs had to be faced realistically; but technically it could have been done with enough advance planning, and settling for anything less was really a waste of time and money. It was a moment for decision, when the Europa I program was reaching full momentum.

The ripeness of the moment did not pass unnoticed. In mid-1966, just before a Ministerial meeting in Paris to determine ELDO's future course, Val Cleaver, a rocket engineer with a flair for making quotable publicity on space issues, saw the matter plainly enough. In a trenchant paper read at a Brighton conference he compared ELDO to a zombie: it was, he said, dead but not lying down. The problem as he saw it was not that it was suffering from any serious technical weakness or a breakdown in international co-operation. Even the ELDO secretariat, while inefficient in some respects, was a victim of circumstances as well; it was remarkable that given the difficulties it had got as much done as it had. The real problem was lack of political will. The objectives of ELDO had not been pursued with firmness and continuity, and governments had constantly proved themselves scrimpers over money, providing too little too late; not only money as such, but engineering and manpower resources. Seeing that there was only muted enthusiasm for ELDO in the other member countries, it was up to Britain to supply the lead. Asking rhetorically of the politicians 'did they really say Yes to space, or were they merely afraid to say No?' Cleaver went on in no uncertain terms to lay the blame at their door:

> Over the whole affair, there hangs a pall of financial gloom—mainly, I regret to say, generated by the British Government, which is now afflicted by doubts about whether the ELDO programs are really necessary, or will ever be effective. It is also my impression that all the other countries want to go on with ELDO, and would follow any more enterprising lead that our country was prepared to give . . . Is our economic position really so difficult that we cannot afford £10 million or even £20 million per annum for ELDO as an investment in the future? (Our present contribution is about £12 million per annum.) We seem to have developed a national genius for spending just below the threshold of real achievement, or withdrawing before we could reasonably have hoped to see any eventual returns. I honestly believe all the other engineers and managers of the ELDO contracting firms are most unlikely to disagree with much, if any, of what I have to say. They—whether British, French, German, Italian, Dutch, Belgian, or Australian—are, I think, as frustrated and disappointed (not to say angry) as I am.[31]

As one of the chief engineers at Rolls-Royce, the company which had developed the engines of Blue Streak, Cleaver was naturally partisan. With his exasperated engineer's approach, his brisk 'can-do' style, he can be accused of being concerned only with means, not ends. In his view the problems would vanish if only the politicians were of the same calibre as the engineers. He overlooked the fact that politicians have to worry about ends as well as means, about priorities as well as what is technically feasible. The facts are that by the time Cleaver wrote the Europa program had more than doubled its cost estimates and had slipped two years behind schedule. Grave dissatisfaction with the rising costs and small success was being openly voiced in governmental circles. Lord Bowden questioned in the House of Lords whether the contribution to ELDO was money well spent. Could Britain really afford to get into space communications when terrestrial communications were in such poor condition?—he reminded the House that Britain's telephone system needed upgrading more than any other in Europe. Another member, Lord Todd, who was chairman of the Advisory Council on Scientific Policy, said on the same occasion that Britons did not need to get into space to earn an international reputation for space research—he evidenced the work of Lovell and Hoyle, who were achieving feats of pure research with their feet firmly on the ground.

Probably it was inevitable that Britain's enthusiasm for ELDO should have peaked early on, when the performance and reliability of Blue Streak were being proven and the goal of launching a satellite still looked appealing and attainable. Once the first phase of the program was completed the British took a back seat; they had proven their vehicle and now they were paying lavishly into ELDO while the other members proved theirs. It was not a very inspiring position to be in. In any case Britain was never more than lukewarm about space, especially once the idea of European independence in satellite communications began to fade away. Even at the height of its involvement in ELDO the country was spending three times as much on atomic research as on space endeavours. Britain's reluctance to continue disbursing large sums now began to disrupt ELDO. They had heard some deep rumblings of discontent, but the other member states were still taken by surprise when, at the beginning of June 1966 the British let fall a cruel blow. 'The Government has concluded', read the official statement in part, 'that the latest proposals for modifying the initial programme still do not constitute a sufficient basis for continuing United Kingdom participation in the activities of the Organisation, and it has so informed its partners.' This was taken universally, at home and abroad, to be a formal notice of withdrawal from ELDO, and it was sharply criticised by the Conservatives (now in opposition) for making the country look like a poor risk for any kind of European collaboration, especially the Common Market. It soon turned out that what Britain really wanted, and succeeded in getting, was a reduction in its share of ELDO's income from 38 per cent to 27 per cent. The government denied that it had ever contemplated withdrawal, a denial which was treated with a certain acidity by the Estimates Committee ('it seems scarcely credible that the statements made by the Government on June 3 and 4 did not mean what they said') but actually it is unlikely that Britain could have withdrawn in any case, since Article 23 of the Convention clearly committed members up to the end of the current program. The other member states accepted the reduction with reasonably good grace, but ELDO's collective will was sadly shaken by Britain's transparent loss of enthusiasm.

That enthusiasm continued to flag. The Labour government under Harold Wilson soon demonstrated that it was just as eager to get out of ELDO as its Conservative predecessor had ever been to get in. It was committed, as it said, to 'the white heat of the technological revolution' but it saw that revolution in terms of computers and the latest industrial plant, not the exploitation of space. On 16 April 1968 Minister of Technology Anthony Wedgwood Benn, conceding that the treaty did not allow immediate withdrawal, announced categorically that Britain was leaving ELDO after 1971, although it would continue to supply ELDO with Blue Streaks until 1976. The intention of Britain now was to concentrate on Intelsat (for the first spaceborne transatlantic telephone system using Earlybird was then being planned), and on its own small Black Arrow launcher. A short time after, when the other partners had agreed to keep to the original budget. Britain announced that the function of ELDO had changed and it would now only supply curtailed funding for the remaining period up to 1971. With renewed cries of 'perfidious Albion' the other partners had no choice but to make up the difference. By the date of its withdrawal Britain had paid into ELDO some $US90 million, and even that sum made no allowance for the enormous costs of developing Blue Streak. It seems a lot of money to throw away; but on the other hand as Geoffrey Pardoe, a commentator on space affairs, said at the time, all Britain was saving was about what was spent every year on fireworks for Guy Fawkes Day, and for this the country was abandoning its launcher ambitions for good.

`But did that matter, really? One can address this question more broadly to the reasoning behind ELDO itself. The fundamental problem with ELDO ran deeper than its clumsy administration or the quality of its engineering. It was that no one examined closely enough the exact operational requirements for Europa; or, in blunter terms, the Organisation was never prepared to face up to the really tough question: 'What is ELDO for?' The mistake was to view the achievement of a satellite launcher as an end in itself, when really it was only a means to an end, the end being to have satellites in orbit under European control. Little attempt was made to secure customers for the completed Europa; which considering its performance, a cynic might say, is perhaps just as well. Although ELDO was founded on exactly the opposite premise, time has shown that the capacity to build a satellite launcher is not essential to gain access to space technology in general and communications in particular. Despite the fears of the architects of ELDO, European access to satellite services has never been hampered. ESRO's successful research program used the services of NASA, and certainly all of ELDO's modest goals except for the actual ownership of a launcher could easily have been achieved if the founding countries had made bilateral agreements with the US. As a matter of fact, by September 1969 NASA had launched no fewer than thirteen satellites for various countries including the three ELDO members France, Italy and Britain. Many more experimental and research packages belonging to European universities had found a place on board US satellites, and neither the launches themselves nor the room supplied in the satellites were charged for, at least in Britain's case. By the same date the meteorological services of forty-two nations were tapping into NASA weather satellites' automatic picture transmission using cheap and in some cases home-made equipment, at no cost. Since then, and contrary to some expectations, ordinary commercial forces have made satellite technology available to anyone willing to invest in it. Indeed, by the mid-1980s fierce competition had arisen between nations and even private firms offering launcher services—a business said to be worth by 1984 more than ten billion dollars a year. By that year even the USSR was offering free insurance to obtain customers for its large Proton launcher. Until the calamity of 1986 NASA's Shuttle was still taking the lion's share, but only because its prices were heavily subsidised, as the Agency itself admitted. NASA's main competitor had emerged as Arianespace, a European consortium of aerospace firms, banks and the French centre for space studies. Arianespace has inherited the mantle of ELDO and still launches from Kourou. On 24 May 1984 the consortium's rocket Ariane I filled its first private order by putting an expensive relay satellite into orbit for a US communications company, and thus in a sense began to move modestly towards the commercial viability its predecessor ELDO had hoped to achieve when it was founded twenty years earlier. By this time Britain itself had apparently put its launcher ambitions behind it, for one government after the other had turned a deaf ear to pleas for a renewed modest national program. In every case Britain has chosen to buy in the cheapest market, bypassing Ariane and having its first three Skynet military communications satellites sent aloft on the Shuttle.

For its part Australia has charted the same course, buying all three of its Aussats off the shelf from the Hughes company of California and launching them on the Shuttle. Successive Australian governments have shown no enthusiasm for fostering commercial interests in space technology, and though this policy—or lack of it—has been criticised by space physicists such as Dr K. G. McCracken of CSIRO as 'calamitous inertia' which has thrown away the opportunity of thousands of man- years of employment, one would be hard put to prove that the country has suffered any real disadvantage from the failures of joint project ventures into space. If the British had grasped the nettle and written off Blue Streak as an expensive failure in 1960 so that ELDO had never been—if the roar of Europa I had never rolled out across the white waste of Lake Hart—it is hard to believe that any of its members, including Australia, would have been hampered in the slightest in their plans to develop satellite telecommunications.

THE JOINT PROJECT AFTER ELDO

It was not the fault of anyone at Woomera, but the departure of ELDO left behind an almost palpable odour of failure, anti-climax and anxiety about the future. ELDO had pumped a total of some $30 million into the joint project funds, including a contribution to the fixed costs of WRE. Directly or indirectly it had employed about 400 Australians at Woomera, Salisbury and Gove and it seemed that half of them might become redundant. Defining it grimly as 'possibly one of the greatest white elephants of all time' the *Canberra Times* summed up in an editorial: 'it is difficult to see that any of it has been worthwhile, apart from giving technicians and scientists exercises in tinkering and humility.'[32] Now, just as it had done after the Blue Streak cancellation, Woomera was forced to cast about for a new focus to its existence. This time the process was the more agonising because ELDO had promised so much and delivered so little; everyone was reluctant to surrender the image of Woomera as a centre of space activity. Once again was heard the optimistic assurance that the Americans would be the salvation of Woomera: this time, so it was said, they were interested in using it as a landing site for the Space Shuttle, then under design. What benefit this could possibly offer either country remained an unanswered question. Instead, over the next few years the gloom was intensified by the rundown of the American moon program and the closing of the facilities at Red Lake and Island Lagoon. By 1987 all that remained of Area 6 was a few broken buildings, a few coils of cable, and the indestructible concrete cores of the launchers squatting forlornly on the margin of the gleaming saltpan.

Notes and Sources

1. Quoted in 'Woomera tests envisaged', *Advertiser*, 8 April 1960.
2. Quoted in 'Messel expects rocket crisis', *Melbourne Herald*, 1 July 1960.
3. Letter dated 18 July 1960 to Permanent Secretary, Ministry of Aviation Sir William Strath. I. L. Knott Papers 1957-60. AA MPI472/8.
4. Quoted in *Flight International*, 22 April 1960, 556.
5. Figures from A. V. Cleaver, 'A space programme for Europe?' *Journal of the Royal Aeronautical Society* (June 1964), 374-82.
6. Quoted in 'European space policy and ELDO', *Flight international*, 10 February 1966, 238.
7. Telex dated 12 August I960 from the Australian High Commission, London to Controller WRE. File A5414/1/10.
8. Participants in the conference were Britain, France, Belgium, West Germany, Italy, Holland, Norway, Spain, Sweden and Switzerland. Australia, Canada, Greece and Turkey sent observers.
9. This judgment may sound harsh, but the Estimates Committee of the House of Commons said late in 1966 that, 'the Government should have treated the original estimate of £70 million with greater scepticism.' *Second report from the Estimates Committee* 1966-67, HMSO, London, August 1966.
10. Among the WRE staff lucky enough to sample the pleasures of Parisian life were V. Bosher, K. Breynard, T. Cooke, P. Dawe, R. Hynes, W. Jackson, G. Lobb, D. Needham, T. Nolan, M. Phillips and R. Rockliff.
11. Quoted in 'UK puts space plan today', *Advertiser*, 14 September 1960.
12. Details drawn from the diary of the late E. G. Foreshew, Principal Safety Officer. Entry dated 10 April 1964.
13. Security Officer's memo dated 29 June 1964 covering McDonald's report on activities at Talgarno. File 56/2888.
14. Memo dated 16 July 1964 from NPO Macaulay to Superintendent Woomera. File S5580/8/2 part 3.
15. MacDougall's report dated 29 June 1964 on his patrol from 12 May-23 June 1964, including his pre-F1 search of the Talgarno area. File 56/2888.
16. Details of the first launch have been drawn from a contribution by Mrs Pauline Windeyer of April 1984 and from an anonymous account published in the *Commonwealth Department of Works Newsletter* of 30 July 1964. On another occasion Mole's suavity suffered a setback when he announced to the far-flung observers down- range: 'I am just about to sire a fighter!' This spoonerism brought an instant retort from a distant female voice: 'And I'm sure no one's better equipped for the job than you, Alan!'
17. Reported in the Bureau of Meteorology's *Weather News* and quoted in *Gibber Gabber*, 13 November 1980.
18. Quoted in 'Blue Streak FI,' *Spaceflight* (September 1964), 169.
19. NPO report dated 17 November 1964 on the pre-F2 search in the Talgarno area. File 56/314.
20. Telex dated 24 September 1964 from Superintendent Woomera to Deputy Director, Trials Wing. File 56/314.
21. NPO report of 17 November 1964.
22. Telex reports dated 19 October 1964 from MacDougall, Macaulay and Long. File 56/ 2888 part 1.

23. Transcript of pre-firing brief by Principal Officer/Ranges on the occasion of the F6/1 launch. The description is representative of all the firings in phases two and three.
24. Reminiscence of the late E. G. Foreshew. Report dated 22 September 1967 by the ELDO Secretariat on the launch of the F6/1 vehicle.
25. *The News* (Adelaide), 15 June 1970.
26. 'An Australian study of a launching site for equatorial orbits' (ELDO Project Study 5.4). Adelaide, Department of Supply, December 1965.
27. Peter Herden, Regional Officer, Department of Community Welfare, Nhulunbuy and Bill Pretty, a local historian of the town, supplied some additional details of the post-ELDO history of the Gove site.
28. Where it was photographed in 1984 by Keith Grant, an artist commissioned to make a series of paintings of an Ariane launch. Information from Mr Grant of the Roehampton Institute, London in a letter dated 13 June 1985.
29. 'One white elephant', *Nature*, 210 (11 June 1966), 1986.
30. 'Britain in ELDO', *Flight*, 28 April 1966.
31. A. V. Cleaver, 'The future of ELDO', *Flight International*, 26 May 1977,'875-6. The article was an abridged version of a paper titled 'The future of ELDO: an industrial point of view' delivered at the Sixth European Symposium on Space Technology at Brighton, England on 23 May 1966.
32. 'A project that barely got off the ground', *Canberra Times*, 1 July 1969.

Part III: The Years of Decline

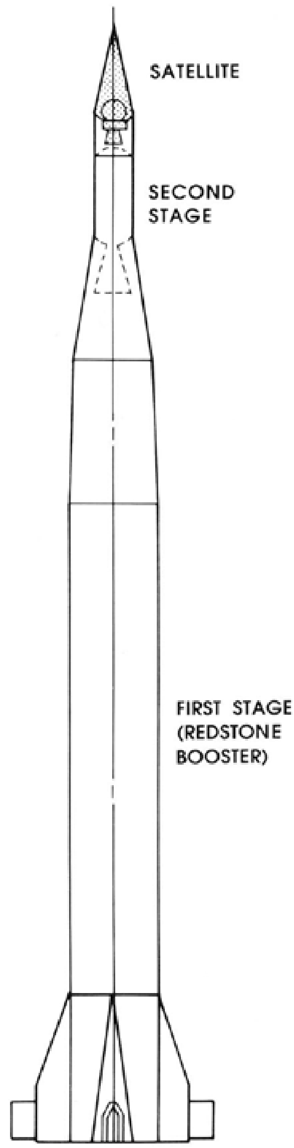
24 WRESAT: *Australia Joins the Space Club*

BIRTH OF THE PROJECT

Did Australia once upon a time really have its own presence in space? Did it really design and build, all by itself, the first satellite ever put into orbit from Woomera? The idea sounds almost fabulous today. Few people, probably, can remember the occasion at all. Yet it did happen, as long ago as 1967, and WRE's satellite WRESAT was, at least from Australia's point of view, both a modest and an outstanding achievement for the joint project. It was far from being the biggest or the costliest or the longest of the many tasks undertaken at WRE. From conception to launch WRESAT took a mere eleven months, and it cost very little. Yet it is memorable on at least three counts. Firstly, by launching a home built satellite from its own soil (admittedly using an American rocket to do so) Australia gained entrance to the exclusive 'space club' ten years after the Soviets astounded the world by orbiting the first artificial moon.[1] Secondly, WRESAT's success came at a very distinct and temporary moment in Australia's technological history. WRESAT was a product of opportunism—in the best sense of the word—when WRE exploited to the full both a windfall American offer and the facilities of the joint project which were then at their fullest expansion. The moment when WRESAT was possible was so fleeting that twenty years later it is hard to imagine that a spacecraft will ever again be launched from Woomera or anywhere else in Australia. As an engineering feat, therefore, it was unique. Thirdly, WRESAT was the only project since the early pioneering years really to seize the imagination of everyone at WRE. The staff of the Establishment worked long hours to bring it to fruition, and it was very much their own triumph. They were rewarded by an unusual blaze of publicity when the launch made headlines in Australia and overseas.

WRESAT was an Australian triumph, but without American generosity it could never have been contemplated at all. During 1967 the United States had been using the Woomera facilities to launch a series of nine rockets to investigate the physical phenomena produced when objects such as warheads re-enter the earth's atmosphere travelling at a high velocity. This was the tripartite Sparta project, paid for by the United States, Australia and Britain, and essentially it was a continuation of the Dazzle program using Black Knight rockets which was described in Chapter 21. Sparta used three-stage rockets: a Redstone booster burning alcohol in liquid oxygen, carrying above it two small solid propellant stages. These vehicles were prepared and fired at Woomera by Americans, including a team from the aerospace firm, Thompson Ramo Wooldridge Systems (TRW), working under contract to ARPA, the Advanced Research Projects Agency of the US Department of Defense.

Where the germ of the idea came from that the Redstone package might be used for a satellite launch in Australia is not known exactly. According to one account, the subject came up during one of those hard-drinking mess sessions that were such a feature of Woomera life.[2] Someone from ARPA or TRW mentioned casually that a spare Sparta vehicle had been sent to Australia just in case, and that the research project was going so well that probably it would not be needed. Everyone at the table was familiar with the history of the excellent Redstone. America's first satellite Explorer 1 had been orbited in 1958 using it as the first stage of another package called Jupiter-C, and since then various other combinations had taken many more satellites aloft. Since some of these were similar if not identical to the vehicles at Woomera, no one doubted that the Sparta rocket could easily be modified to orbit a small payload from Australian territory. And if a spare was going begging . . .



The WRESAT satellite was Australian designed and built, but it was placed in orbit by an American three- stage rocket left over from a previous program of trials. The first stage was the tried and tested Redstone, developed from the German V-2.

Jeff Heinrich (*top*) and Peter Twiss. They suggested the idea of a WRE satellite to Director Don Woods (B*elow*).

Arthur Wills. He gave the go-ahead for early planning work on WRESAT.

These broad hints came to the ears of Jeff Heinrich, who, as Superintendent Trials, was responsible for the range and for the conduct of the firings there. He spoke at once to Peter Twiss, the Superintendent of Systems Assessment Division (SAD). Within Twiss's Division was a small Flight Projects Group headed by Bryan Rofe, which had long been engaged on a program of pure scientific research into the upper atmosphere, in conjunction with a team of some forty-five staff and graduates of the University of Adelaide's Physics Department. As described in Chapter 20, Rofe's team had grown experienced in launching experiments aboard sounding rockets, and would obviously be excited by the prospect of a research satellite, however modest. Together Twiss and Heinrich went back to the Americans and suggested to Ed Fronefeld of ARPA and Dean Carpenter of TRW that perhaps the spare rocket could be put to good use in launching a small satellite, rather than being shipped back to the States and perhaps ending up on a dump. The Americans liked this idea so much that they immediately made an informal offer not only of the rocket but also the use of their team to prepare and fire it.

On hearing this Twiss and Heinrich lost no time in taking the suggestion to WRE's Director, Don Woods, and the three men chewed over its pros and cons. There were some difficult hurdles to jump. The American offer was unofficial and would have to be confirmed. The support of the Australian government would have to be sought and won. Then one had to bear in mind the possibility of failure. The launching of satellites is a high risk occupation, and the overall record at Woomera was not to be very good: of the six attempts made to orbit a satellite, four were failures. As we have seen, ELDO's Europa vehicle never succeeded in its attempts despite years of effort and a huge budget. ELDO was of course a Range user, and WRE was not usually answerable for its technical problems. If its own satellite failed, however, the Establishment's public image, about which it was defensive and jealous, might be affected.

Yet perhaps this was being unduly pessimistic. The Redstone was a tried and tested rocket. Unless something unpredictable happened, its third stage would reach orbit. Designing and building a simple satellite for it to carry was a comparatively modest task, though still hard enough in the time available.

For overshadowing everything was a shortage of time. It was now December 1966. The Americans would be finished in eleven months' time, after the last Sparta trial, and could not linger in Australia afterwards. Could a satellite possibly be designed, built, tested and launched in less than a year? Certainly it would be a close thing. Normally for a project on this scale the planning alone might be expected to take longer than that. Yet despite his misgivings Woods found himself being caught up by the enthusiasm of Heinrich and Twiss. It could be done; it ought to be tried. He agreed to lend his voice to the proposal.

The first step was to secure the blessing of the Department of Supply, for without that nothing could be done. Woods, Heinrich and Twiss caught the early morning plane to Melbourne and after a late breakfast at Essendon took a car to Swanston Street. They found the usually humming offices almost deserted. It was the Friday before Christmas and everyone was at a party in a nearby hotel. Woods and Twiss cooled their heels until the jovial Chief Scientist, Arthur Wills, returned from the celebrations.[3] When the idea was put to him, Wills, who had taken over the top job from Butement not long before, took little convincing; he promised to get the Minister on side and meanwhile he gave permission for the planning to start. The race was on.

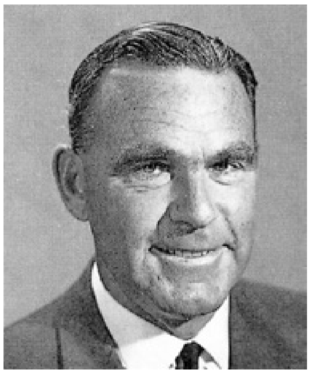
Events moved quickly after that, and the first hurdles did not prove so formidable after all. Wills was as good as his word and secured the support of the Minister for Supply, Senator Denham Henty. Henty succeeded in getting the funds from Cabinet without too much difficulty. Funds were still flowing without very stringent inquiry into anything that looked even vaguely 'defence related', and the first tough investigation into WRE's activities was still a few years away. Henty used a number of hard-headed arguments. One was that the WRESAT task would give the Range some practice for the forthcoming ELDO and British Black Arrow launches. Another was that the data collected by the satellite would be intrinsically valuable because it built on the sounding rocket work. The argument that Cabinet found most compelling, though, was simply that WRESAT offered a good measure of national prestige at a cheap rate. Australia would not be spending its money alone. It would be paying for the design, construction and testing of the satellite and for some of the on-board equipment such as the transponders and the telemetry, but the launch vehicle was free and WRESAT's use of the Range could be billed to the joint project, to which Australia's contribution was a fixed and already committed sum. Part of the cost of the experiments would be met by Adelaide University and be paid for out of a budget which derived a third of its funds from USAF sources. All in all, a fair judgment would be that Australia joined the space club at a very discounted price.

The other pieces fell into place easily. The British had their hands full with their own Black Arrow launcher and did not wish to take a direct part; but they agreed to the use of the joint project facilities providing they were given access to the experimental findings. The US Department of Defense confirmed the offer of a Sparta vehicle and the services of the TRW launching crew. NASA agreed to track the satellite with its global network of stations and to donate the recording tapes. The Agency's encouragement and advice later proved invaluable, particularly the services of one of its managers, Gil Ousley. He became a 'Mr Fixit' for WRESAT in the States, by arranging a visit for WRE engineers later in the year and by liaising with the builders of the telemetry gear. The NASA aid was freely given, and indeed the only substantial cost of the launch paid by Australia to the US was to TRW for the reprogramming of the Redstone's inertial navigation system to the new orbital trajectory. The American gifts in connection with WRESAT were worth at least one million dollars at 1967 prices, and came from no other motive than to encourage international co-operation in space, coloured perhaps by the thought that it would be fun to offer the means of getting into orbit to little Australia, which had been freely contributing to the NASA space tracking network for the past decade.

Soon after Christmas the WRESAT team began to take shape. Director Woods decided that because Bryan Rofe's Flight Projects Group had handled the sounding rocket work and was used to liaising with the University, this group should oversee the design, construction and testing of the satellite. Rofe spent many hours at the University helping to work up the on-board experiments with Professor John Carver, Dr Brian Horton and others. Carver, who had held the Elder Chair of Physics since 1961, was a dedicated scientist who was immensely proud, and with good reason, of the team over which he presided. Carver was right behind WRESAT; but he may have been mindful of the risks of being too closely linked with a project which might flop dismally.[4] Much of the detailed work fell to Brian Horton, a relatively junior member of staff. As for the WRE effort, opinions differ about Rofe's contribution. Twiss described him as the chief spirit behind WRESAT, but other views are less generous. The majority view is perhaps that Rofe's strengths lay not in theoretical science nor in painstaking detail but in his sheer enthusiasm. He amply filled the role of a friendly extrovert who normally got his way by jollying people along, but if this failed he could be almost tyrannical. Certainly his enthusiasm was infectious as far as Carver was concerned. Carver was withdrawn and rather shy, but he reacted positively to Rofe's bubbling enthusiasm and an unlikely friendship sprang up between the austere academic and the cheerful WRE man. Carver and Rofe lived close by each other in the same Adelaide suburb of Beaumont and their families were friends. This neighbourliness and the network of personal and scientific connections shared by Carver and Rofe helped immeasurably in smoothing the way for the experimental part of the project.

John Carver, Professor of Physics at Adelaide University. His research workers designed the WRESAT experiments, with WRE co-operation.

Back at Salisbury a good deal of the hard slog was being done by Phil Pearson (who eventually succeeded Rofe as head of the group) and by the quiet Frank Burger. Other important names were Peter Pemberton, a mechanical engineer who designed and built the fabric of the satellite, and Paul Gillard, an immensely experienced electronics man, who came up with a suitable telemetry system.[5] As the pace built up in February and March, Woods realised the size of the management task ahead. It needed great attention to detail, not only to co-ordinate the separate groups scattered throughout WRE but the critical inputs from NASA, the University and various contractors. Woods decided to set up a project management cell and chose Des Barnsley to lead it. Barnsley had several valuable assets. He had a long background in RTV1 experimental rocketry. He had recently returned from the United States, and had contacts inside the TRW team. He had come back to a less important job which rather disappointed him, and therefore he was available. Perhaps most importantly he had just the sort of friendly yet conscientious approach that could get results. Rofe was unhappy with this outcome, but he continued as Officer in Scientific Charge.



Des Barnsley: a friendly yet conscientious approach to WRESAT management.

THE EXPERIMENTS

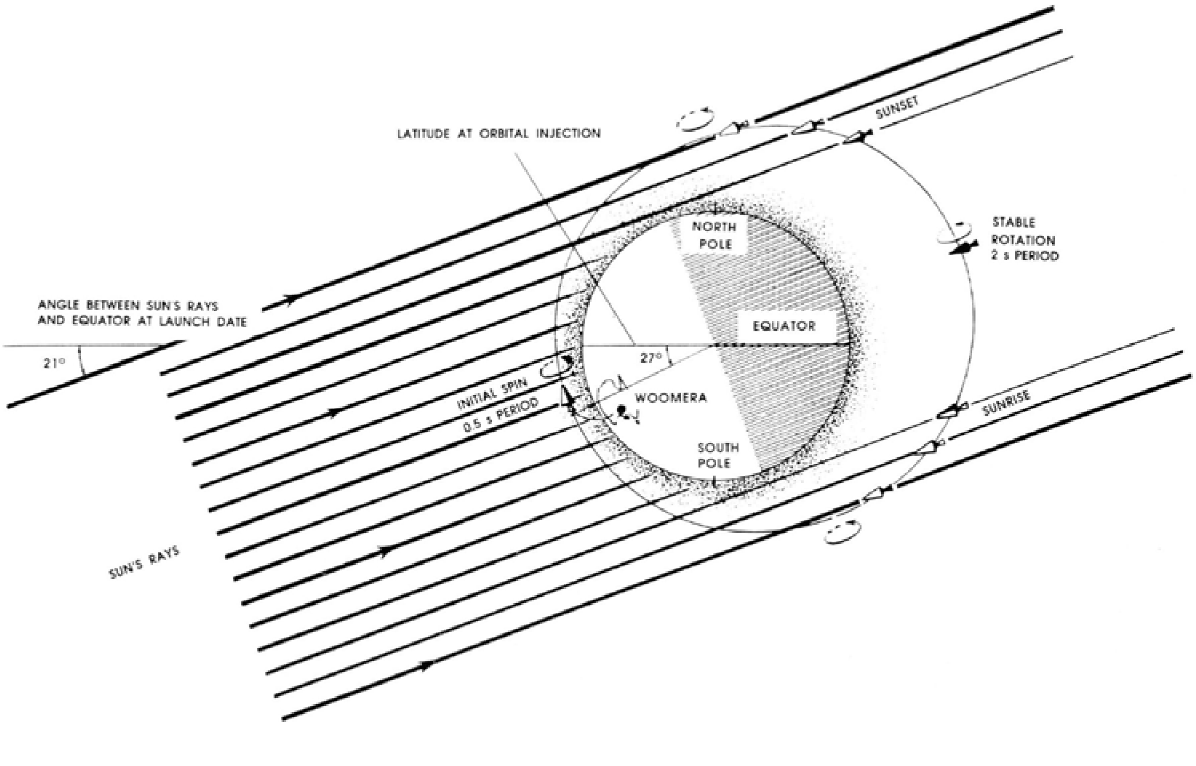
One of the earliest decisions was to send WRESAT north into a polar orbit using the same flight path, slightly east of due north, which had first been used for ELDO's F4 flight the previous May. This was no hardship in WRESAT's case, for it meshed well with another basic decision. This was that the instruments aboard WRESAT should be very similar to those which were being used in Woomera's sounding rocket program, which included packages launched for Adelaide University. The purpose of these flights, handled by WRE for a variety of international 'customers' and described further in Chapter 20, was to probe the furthest reaches of the atmosphere. High in these inaccessible regions, where the last wisps of air give way to the vacuum of space, the vigorous radiations from the sun drive physical and chemical processes which in many complex ways influence the biosphere below. The sounding rocket program was having good results, but a detector carried in a rocket has its disadvantages. It can only make brief measurements over a small area. A satellite can take prolonged measurements at every point on its path right around the globe.

WRESAT therefore carried detectors and recorders of the solar radiation on three of the wavelengths which most directly influence the temperature and composition of the upper atmosphere. These same instruments could also measure the temperature of the sun's atmosphere which does not, as one might suppose, fall uniformly with the distance from the solar surface: it falls at first, but then rises again in the region of the excited gases of the corona.[6] The sensors were ion chambers (two sets of three) to measure ultraviolet radiation, X-ray counters, and a photocell with a filter which passed only light of a wavelength that is strongly absorbed by ozone. The polar orbit allowed these experiments to gather data on the atmosphere from all latitudes between the equator and the Arctic and Antarctic.

Another experiment exploited the fact that the satellite saw a sunrise and a sunset on each ninety minute orbit. The ion chambers could measure the density of molecular oxygen by measuring its absorption of the sun's rays each time the satellite went through sunrise and sunset. The phenomenon exploited in this experiment is similar to the bloating and reddening of the sun's disk, apparent to an observer as it drops down to the horizon: this happens because more and more of the sunlight, or selected wavelengths in it, are being absorbed as it passes through a progressively thicker stretch of the atmosphere.

Carver and Rofe also planned a geocoronal experiment. A small telescope with special lenses of lithium fluoride would look at and measure the faint ultra-violet halo that surrounds the earth at night, caused by hydrogen atoms scattering sunlight at the wavelength known as Lyman alpha.[7] Identical experiments had already flown at Woomera in Long Tom sounding rockets, but the new opportunity gained impetus from the fact that the

The initial spin of WRESAT soon decayed to a stable end-over-end rotation. The launch time and date was such that forward facing sensors in the nose scanned across the sun on each rotation, and one of these sensors measured atmospheric absorption during sunset and sunrise on each orbit.



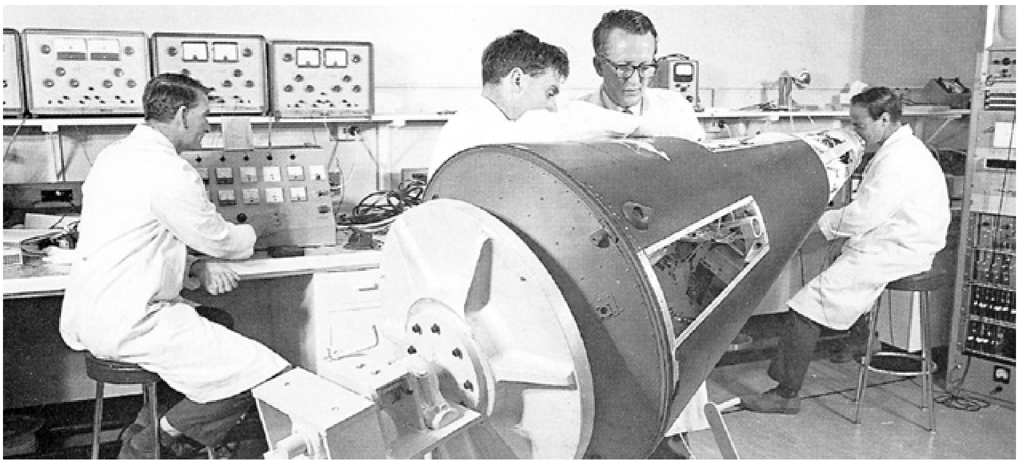
sun was reaching the peak of its eleven-year cycle of activity, when sunspots are constantly forming and solar flares, with their accompanying radiation storms, are frequently being thrown off the solar surface.

Although WRESAT maintained the appearance of being a scientific project, and was presented throughout to the government and the media as such, it was an open secret from the beginning that it would not be doing any grand science. The reason was simple. WRESAT was powered by batteries, because it was impossible to design an array of solar panels in the time available. The batteries gave it an operational life of a few days only. This was long enough to collect a great deal of data on conditions in the upper atmosphere along a whole belt girdling the earth, but such data could not be greatly significant. The purpose behind this sort of upper atmosphere research lay in seeing how the levels of ozone and molecular oxygen vary over time, and then in trying to explain why they fluctuate. For this a sampling period of at least a year was essential. Nothing of any predictive value could be deduced from data gathered in less than a week.

DESIGNING AND BUILDING WRESAT

Early in 1967, after discussions with the Sparta teams, the WRE men decided that to simplify matters WRESAT would be integral with the third stage of the Redstone package and would go into orbit attached to it. To help achieve an accurate insertion, the second and third stages plus the satellite were 'spun up' by small rocket motors. Thus WRESAT entered orbit spinning around its long axis like a rifle bullet at the moderate rate of two revolutions a second. For a while this spin continued and WRESAT maintained its attitude with its long axis pointing constantly in the same direction in space and thus perpendicular to the sun which was overhead at orbital insertion. But gradually its attitude changed. Because of the energy absorbed by slight flexing in the structure, the satellite's smooth drill-like rotation began to nutate; that is, to cone outwards, with the same kind of wobble as is shown by a top when it loses momentum. This effect grew more and more pronounced until eventually the satellite was rotating end over end around a short axis perpendicular to the long axis. At different points in its orbit it looked, with respect to the earth's surface, now like an aeroplane propeller, now like a flat stone skimming across a lake. This was the stable state, as the short axis assumed was that of maximum inertia. It was also the desirable state. Once it was achieved the two sets of sensors and the short axis were all at right angles to each other, and since the axis of rotation now pointed in the same direction in space as for the earlier 'spinning bullet' mode, both the sensors in the nose and those facing sideways each scanned across the disk of the sun once. WRESAT contained an energy dissipator to speed up the transition to the propeller mode. It was a closed loop of tubing filled with silicone oil, and worked on a simple principle: the rotation of the satellite drove the fluid to and fro around the loop, and the viscous oil dissipated the rotational energy as heat.[8]

Designing and building the satellite went ahead quickly in the early months of 1967. In June a team of three from WRE—Phil Pearson, Bryan Rofe and Paul Gillard—visited the United States and then RAE. They spent a busy two weeks in Los Angeles and elsewhere



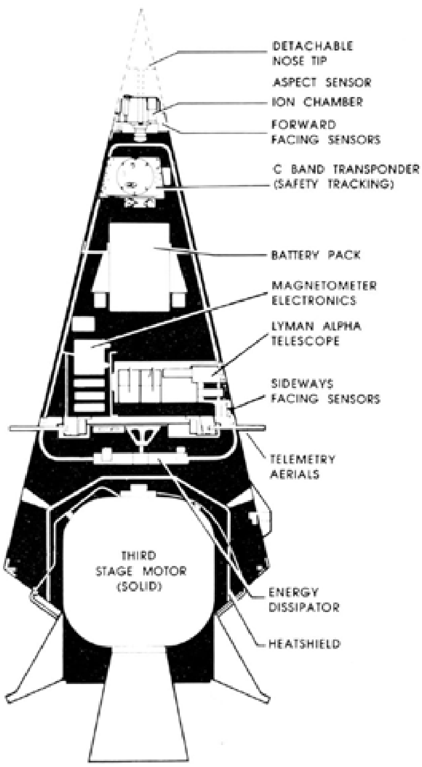
Flight Projects Group staff at work on the satellite. Phil Pearson is second from the right.

finalising the launch agreements, buying the major telemetry components and picking the brains of the staff of the Goddard Space Flight Center in Washington. Several design changes were needed as a result of this visit, but fortunately all were minor.

WRESAT (or to be precise the orbital package consisting of the satellite and integral third stage) finally took shape as an aluminium alloy cone a little over 2 metres long weighing 72.5 kilograms. Thus it weighed less than the first Sputnik. WRESAT's skeleton was a number of long bars or stringers arranged in a cone and braced along their length by parallel rings. The whole was strongly riveted together and covered by a thin outer skin. Inside the satellite proper were all the instruments: the forward-facing radiation sensors in the apex of the cone and the sideways-facing sensors along its flank, the measuring devices fed by these sensors, a magnetometer package (rather like a magnetic compass) and two optical sensors for determining the satellite's attitude accurately, the safety tracking system, the telemetry system, the energy dissipator, a temperature control system and a common power supply. Both the sensor ports were protected during the ascent by small covers that were afterwards ejected by firing explosive nuts. Apart from these covers the only protrusions were the telemetry and safety system aerials.

One interesting feature of the satellite was the method of regulating its internal temperature. Unlike most satellites of the time WRESAT rose into orbit naked, without the usual detachable covers protecting its skin. (The aerials were covered by cork sheeting, and a heat shield of aluminium foil and glass cloth protected it from the heat of the third stage motor, but most of the cone was exposed.) After many complex calculations and experiments the outside was painted mostly black with some silver striping, to give just the right balance between heat absorbed by the sunlit areas and radiated by the shadowed parts; and there were some fears that even though the paint was heat resistant it might deteriorate under the friction heating as WRESAT passed through the lower levels of the atmosphere. Inside, the cone was painted white to distribute the heat evenly. The white paint was selected on American advice, and was imported for the job at considerable expense. No fewer than fifteen quick-drying coats had to be applied, and they were put on by Phil Pearson and Don Paginton in one marathon 48 hour stint, broken only by sustaining visits to the pub. Only much later, when nothing could be done about it, did it come to light that paint of the wrong specification had been shipped; its properties were no different from those of any household white enamel! But despite everything the regulation system worked perfectly, and the internal temperatures were within a couple of degrees of the predicted figure for the whole telemetered flight.[9]

Don Paginton: a marathon 48-hour stint to paint the cone inside.



Some of the instruments that were packed into the orbiting WRESAT third stage.

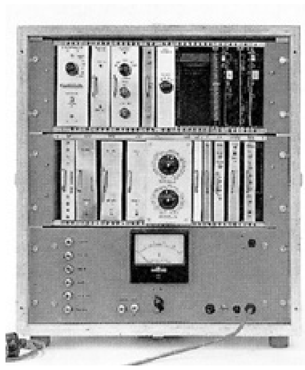
By the beginning of October WRESAT had been assembled. The cone was thoroughly tested under the punishing conditions it would be encountering at launch and in orbit. There were vibration tests and centrifuge tests. There were also drop tests in which the complete satellite was allowed to fall from a height on to a block of lead, subjecting the cone on impact to a deceleration of up to 40G. All but two of the tests were done at WRE. The satellite had to be dynamically balanced, and this was done on the premises of Reed and Walker, the motor engineers, using Repco equipment which normally handled truck engines. The hot and cold soak in a vacuum lasting a full week needed the large vacuum chamber at the University of Adelaide. Here there was some delay in pumping the chamber down to a vacuum. It turned out that WRE had forgotten to put the sealing plugs in the batteries. As the air pressure fell, the electrolyte started to boil off, a lapse which produced some acerbic comments from the Physics staff.[10]

WRESAT'S TELEMETRY

The telemetry equipment on WRESAT had a dual purpose.[11] Through its tiny tenth- watt transmitter it could send back data from the fourteen scientific instruments and the fifteen 'housekeeping' functions such as the internal temperature, the state of charge of the batteries and so on. In addition, its transmissions served as a beacon: they were the means by which WRESAT could be tracked by NASA's global Space Tracking and Data Acquisition Network (STADAN). The STADAN stations recorded the telemetered data as well, but they could not interpret it as only WRE had the necessary demultiplexing equipment to unscramble the signals. This was a nuisance, for it meant that, before launching, the satellite had to be transported to the nearest STADAN station in Australia (Orroral Valley, near Canberra), together with some specially developed demultiplexers. Tests there would establish beyond all doubt that the network could lock on to and record the WRESAT signals, and that WRE could afterwards process the data.

While it was clear from the outset that the on-board telemetry transmitter would have to be compatible with the STADAN receivers, perhaps less obvious was the need for a receiving station at Salisbury to assist in developing and proving the on-board telemetry. Furthermore a Woomera ground receiving station would also be essential. How else could it be shown that the vehicle had successfully withstood its trip to Orroral Valley and to Woomera and had been mounted intact on the third stage rocket? And what if it failed on the launcher or in the vital lift-off and early flight stages?

The obvious answer was to build a transportable telemetry receiving station. It could be used to check out the vehicle in its final stages of development at Salisbury, and then taken to Woomera to monitor the telemetry signals during launch and insertion. If coupled to a suitable high gain tracking antenna, it could afterwards follow the satellite for many of its passes from horizon to horizon, and thus provide the only 'housekeeping' measurements which would be available instantly.



Part of the hurriedly assembled telemetry receiving equipment.

At first sight it appeared impossible to get such a station ready in time. The receivers and other specialised equipment could not even be delivered by then. The day was saved by a laborious search through the Establishment's junk stores, which brought to light many of the essential components. The biggest find was a high gain antenna capable of manual tracking, albeit in need of extensive refurbishing. Other items were borrowed from various sources, including the Orroral Valley STADAN station. With perhaps a little bit of luck Lance Anderson and his small team had the station at Woomera ready and operational by the morning of 28 November, the day planned for the launch. The new telemetry station was designated M32, and it was to carry out its role with distinction during launch and for some days following while WRESAT was transmitting its data. This despite problems with the manual tracking antenna controls, which had about 12 degrees of backlash: worse than one would hope to find in the steering of an old car.

The satellite's telemetry transmitter came off the shelf from an American firm, as designing and manufacturing one in Australia would have taken far too long. In fact time was so short that a courier, Colin Holbrook, went to the States to oversee the final tests and to bring back the two devices—one was a spare—in his personal luggage. The manufacturer had responded magnificently and produced the units to the exacting specification in just eight weeks, which included an eleventh-hour rework. It was something of an anti-climax when Holbrook arrived back in Sydney only to find that his luggage, transmitters included, had been left behind somewhere en route. Fortunately everything turned up undamaged on the next day, before the recipients of a flood of urgent telephone and telex inquiries had had time to reply.

WRESAT SAFETY

As with all major long range Woomera trials, the second stage of the Redstone package was equipped with the WREBUS break-up system. Obviously a cut-down action would be taken even less lightly than usual. The Redstone and satellite together were worth several million dollars. There were no more rockets and no back-up satellite. Pressing the destruct button would be devastating, but everyone knew that it would be done without a qualm if the safety boundaries were breached. Woomera's reputation as a safe Range depended on this tough philosophy.

To help the Flight Safety Officer make the right decision, a sophisticated safety tracking and display system was set up. The early ascent of the Redstone was watched by observers using skyscreens and optical trackers. The two powerful precision FPS-16 radars then tracked the C-band transponder beacon in the satellite right through to orbital insertion. In the Instrumentation Building the Digital Impact Predictor (DIP), developed first for Blue Streak and then used for the Europa flights, was available to give a walking impact point. To cover the special characteristics of the WRESAT flight, the DIP was fed with a program written to protect New Guinea from accidental impact.

Peter Oswald. He built the WREBUS transmitting station for Oodnadatta.

Despite the familiarity of all the safety equipment a crisis still developed just twelve weeks before the scheduled launch date. The WREBUS transmitters were at the rangehead, and the unusual northerly trajectory of the vehicle would put the flame from the second stage in line with their transmissions to the WREBUS receivers in the second stage. Nobody was quite sure just how much the flame would attenuate these signals, or at least no one was confident enough to assure George Foreshew, the Principal Safety Officer, that an adequate WREBUS signal would get through to the vehicle during the critical thirty seconds of second stage burning.

In the few short weeks remaining, Peter Oswald was given the daunting task of providing a new WREBUS transmitting station, to be positioned far enough down- range to get a sideways look at the ascending rocket. The airfield at Oodnadatta was selected. It was in the right place, near the railway line to Alice Springs and with good communications. WREBUS had to be totally reliable as well as fail-safe, so Oswald's team was faced with designing a lot of redundancy into makeshift equipment. For the link back to the Flight Safety Officer's destruct button at the Range, one of the three precious land-lines that gave Darwin its telephone link to the south was temporarily commandeered. To make quite sure, two radio links were also used to carry the same message. The WREBUS radio transmission to the rocket was treated in the same belt and braces fashion, with triple redundancy against failure built into the system. With the time to go being measured in hours rather than days, the new station was railed to Oodnadatta and commissioned just before the launching. Fortunately the second stage showed no sign of going astray so WREBUS did not have to perform. As one tired technician lamented after he had sweated in 41 degrees at Oodnadatta, 'all that work and the bloody station wasn't even used!'[12]

The WREBUS van

WRESAT ENTERS ORBIT

The last panic at Salisbury arose less than six weeks before launch with the discovery that WRESAT's mass was several kilos over the 70 kilogram limit set by TRW. There followed a crash program to slim it down. The structure was lightened somewhat but it was not enough; and at a meeting attended by Barnsley, Rofe, Carver and Horton the tough decision was taken to remove one complete experiment and two of the three magnetometers. Horton bitterly resisted the latter move, because leaving just one magnetometer meant that the precise attitude of WRESAT in two planes could not be calculated during the dark part of its orbit. The opposing rather feeble argument was that one magnetometer together with the optical sensors might suffice. Horton knew full well that this was not so, and that the geocoronal experiment would be ruined; and he was right. However, it had to be done. No one wanted to risk having the mass pushing right against the limit, for there were some unquantifiable imbalances in the second and third stages that just might have made a critical difference. Ironically, all the panic was quite unnecessary. The Physics team had no direct contact with the Americans. They relied on Rofe for liaison, and oddly enough no one questioned his report of a rigorous 70 kilogram limit. Only when it was too late did Horton discover that TRW had offered it merely as a working limit. The Sparta vehicle had ample reserves of power to cope with any reasonable increase in the third stage mass.[13]

As soon as the completed WRESAT had passed its tests at Salisbury, the RAAF helped out by flying it to Orroral Valley for telemetry checks and calibrations, and thence on to Woomera for integration with the third stage motor. Here the Americans had been working hard in assembling and checking the first two stages, and now they turned enthusiastically to mating the final satellite package to the Redstone vehicle.

All was ready for the planned launch attempt on 28 November 1967. The countdown started at 8.19 a.m. and proceeded smoothly through the morning. Then just thirty seconds from zero a heater-cooler unit failed to eject from the side of the Redstone, causing an automatic stop. The ball lock release mechanism had malfunctioned. One of the Sparta team casually offered to climb up and yank out the unit by hand, but was dissuaded from doing so. Instead the rocket was recycled for a launch on the following day. The false start was a disappointment to Minister Henty and others in the VIP party, who had come to Woomera specially to witness the launch and could only spare one day. The Range staff could accept it philosophically, as they had experienced such frustrations many times in the past.

The pressmen who had been flown up to report the historic launch reported instead the anti-climax of the aborted attempt; one of them noted that the million dollar rocket had failed to launch because of a failure in a device worth only five dollars.[14] The TRW team' was more than a little mortified, for their nine previous launches had gone without a hitch. However, all the Range staff drowned their sorrows by converting that night's 'launch' party into an 'abort' party, which saved some of them the inconvenience of having to get up early the next day to go to their tasks.

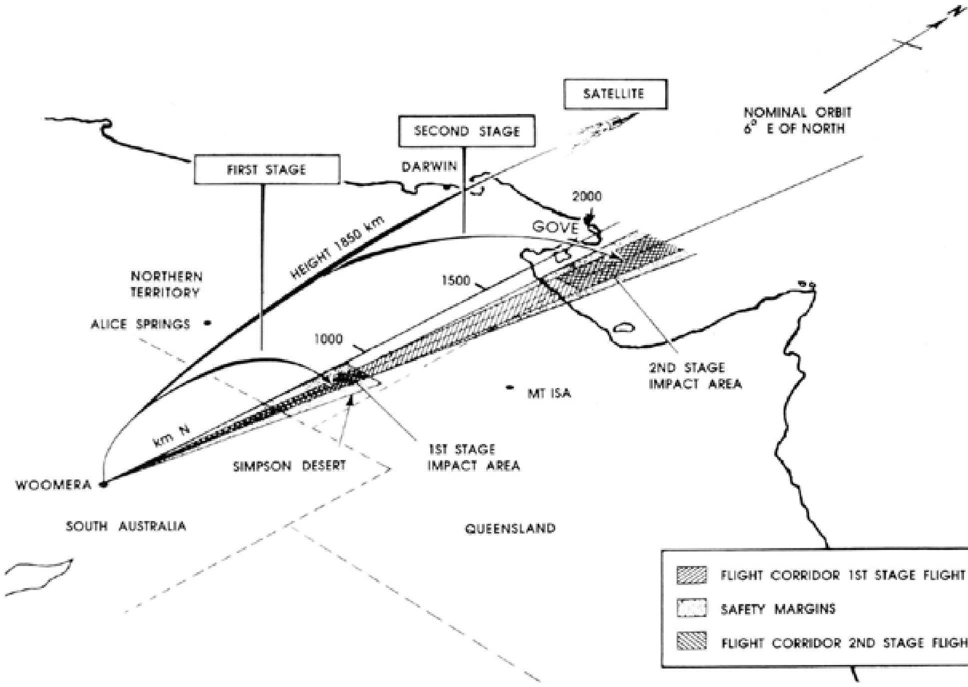
The long six-hour countdown through the morning of Wednesday 29 November proceeded faultlessly. At 2.19 p.m., right on schedule, the white 21 metre tall Redstone climbed into a hot blue sky, its black kangaroo and WRESAT emblem gleaming on its side. The cheers of the onlookers were soon drowned by the roar of the rocket motors. A few seconds later the inertial navigation system took over, and the Redstone vehicle gradually arched over northwards along its planned trajectory. Then just two minutes after launch came reassuring calls over the intercom speakers of first stage burn-out and separation.

As the battery of safety trackers and behaviour cameras and kinetheodolites and radars tracked the ascending rocket vehicle, anxious eyes watched the pens of the plotting tables trace out the flight path and the predicted impact point. All was well so far. The trajectory was nearly perfect and there was no danger of transgressing the flight corridor, nor any question of having to destroy the vehicle in flight for the sake of safety.

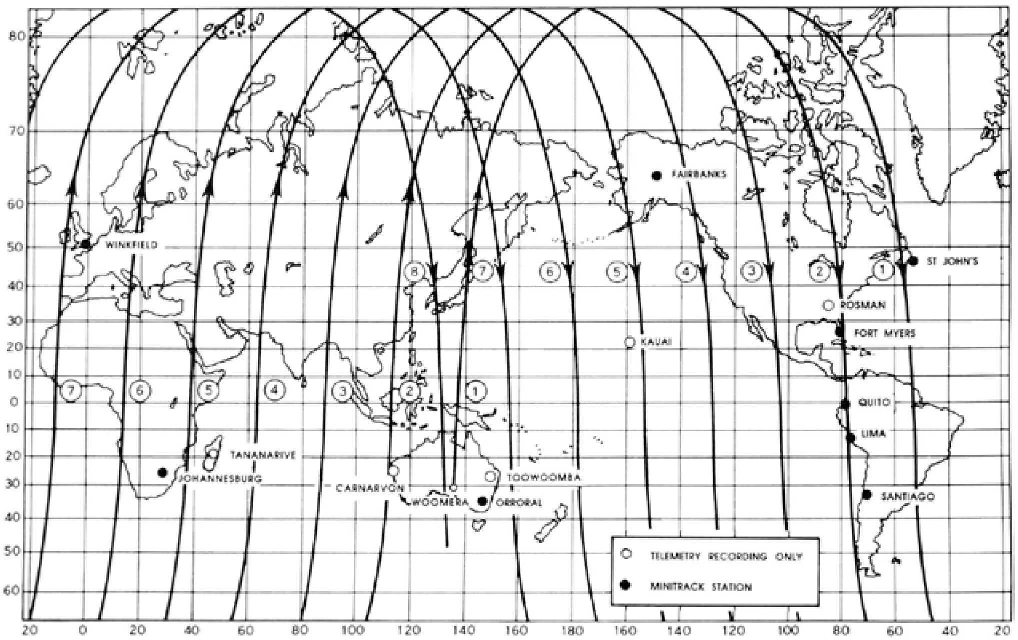
The exhausted first stage fell according to plan in the Simpson Desert and has never been reported found. The second and third stages and satellite coasted on and up, while—so it was hoped—the inertial navigator was nursing the package into a horizontal position. Then at 180 kilometres the small spin motors fired, the second stage burnt for thirty seconds and was jettisoned into the Gulf of Carpentaria, and finally the still spinning third stage with its attached cone fired for nine seconds. If all had gone well WRESAT had now reached orbit.

Back at the distant Woomera, a plotting table indicated that WRESAT had reached the expected velocity of 30 000 kilometres per hour, enough to achieve orbit providing it had been inserted at the right angle. The new rangehead telemetry station M32 reported that telemetry signals were good, and further that the satellite equipment had obeyed all the commands, culminating in the release of covers protecting the forward-and sideways-facing experiments. Then right on time the ELDO down-range tracking station at Gove in Arnhem Land reported receiving signals. Clearly the all important satellite instrumentation had survived the buffeting by three rocket stages. Excitement at the Range was reaching fever pitch, and many were already convinced that WRESAT was in orbit.

By this time most of the staff had been stood down, their work complete. Many made off through the sweltering afternoon—there was a howling northerly wind and a dust



The flight corridor and early stage impact areas for the northerly WRESAT launch.



The path of WRESAT on its early orbits and the NASA stations that tracked and recorded it. A report from Carnarvon on the first orbit proved that Australia had successfully launched its first satellite.

storm—to start the mess celebrations. But one small group remained in the emptying Instrumentation Building, monitoring the reports coming in on the NASA net from the STADAN stations in the WRESAT path. They were well aware that achieving orbital velocity at insertion does not mean being in orbit. If WRESAT had been inserted at too high an angle it would plunge back into the atmosphere before completing one orbit.

Guam was the first of the STADAN stations to report receiving signals from the beacon, followed by Fairbanks in Alaska. Interestingly, the signal fluctuations received by Fairbanks showed that the spin rate had already decayed from 2 to 0.7 revolutions per second. The transfer of the spin axis to the propeller mode, which had been expected to take a whole orbit, was already almost complete. This was probably because the third stage motor had more flex in it than had been anticipated. Later the STADAN stations in the north to south leg of the orbit reported signals as WRESAT crossed over—first St Johns Newfoundland and Rosman in Carolina, and then in turn the South American chain of Quito, Lima and Santiago.

It was still too early to say positively that WRESAT was in orbit. That would have to await a report from Carnarvon in Western Australia, to confirm that the satellite had circled the earth once. Nevertheless there was by now little doubt, and the bouquets were already arriving. First on the net was Minister Henty, now back in Canberra. He had to be kept waiting a short time while reports were being received and discussed on the net. The Senator warmly congratulated 'the boys and girls at WRE and Woomera', and thanked the Americans and British for their help. Then after the Santiago crossing it was the turn of the Americans, more hard-bitten in the space game than the new-chum Australians. NASA official Jack Mengel called up Bryan Rofe on the net from Washington to congratulate him on a very excellent performance, adding that there was no country he would rather have in the space act than Australia. It was a generous US welcome to the newest member of the space club, and Rofe's voice betrayed more than a hint of emotion as he thanked Mengel.[15]

After Santiago there seemed to be a long gap, but in fact it was only twenty-five minutes as expected. Carnarvon picked up the signal from the tenth watt telemetry transmitter. WRESAT was undoubtedly in orbit, proudly bearing its white kangaroo transfer as a symbol of Australia's success in orbiting its first satellite in history.

WRESAT bore the international reference '1967-118A'. Its initial orbits of ninety-nine minutes took it very nearly over both Poles, at a height which ranged from 169 kilometres (perigee) to 1245 kilometres (apogee). It continued to relay data from the scientific experiments for seventy-three orbits, or about five days. Although its useful scientific life ended at this point, enough power remained in the batteries to sustain transmission for another five days. After that the silent and invisible WRESAT continued in orbit until just before noon (GMT) on 10 January 1968, when it finally burnt up in the atmosphere over the Atlantic Ocean, somewhere between Ireland and Iceland.

WRESAT EUPHORIA

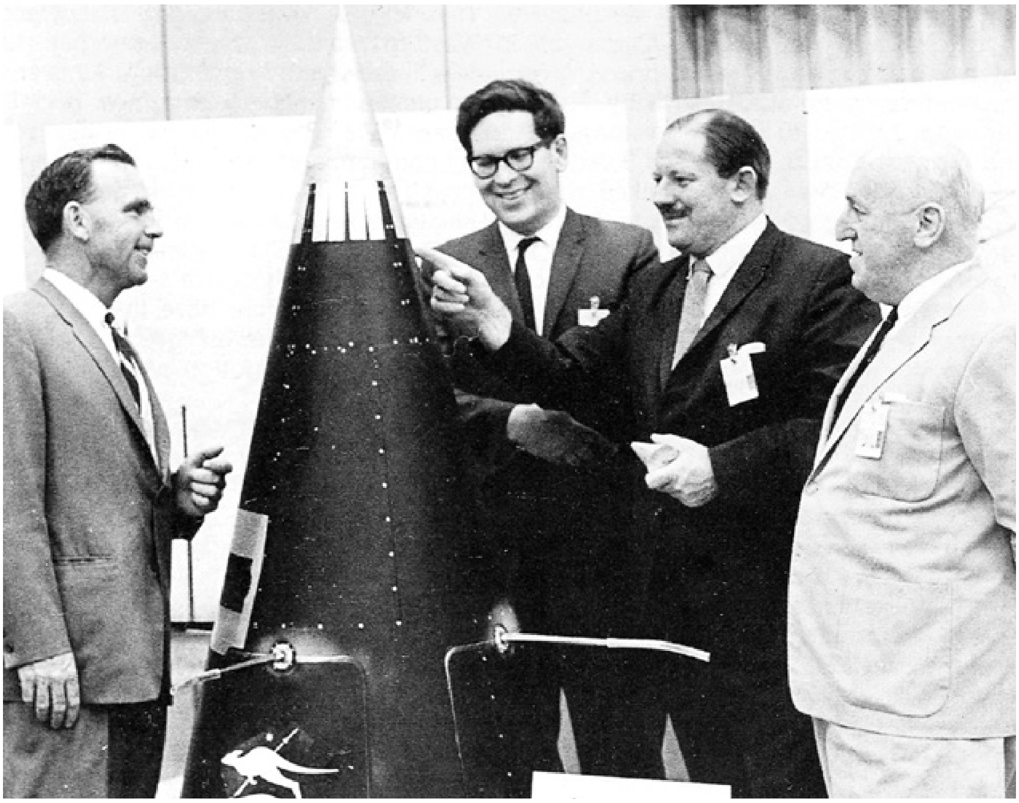
The WRESAT launch was highly public. The media had been entertained at Woomera on both days, and their graphic accounts filled the newspapers and airwaves across the country. The description of the ABC's Dr Peter Pockley went live to air, including the reports from the STADAN stations around the world and the final confirmation of orbit from Carnarvon. There was even a radio broadcaster from Indonesia.

Over the next few days the messages of congratulation poured in. Prime Minister Harold Holt described the launching as a notable scientific achievement, demonstrating a remarkable advance by Australia in this field. Senator Henty added that 'all Australia will applaud you'.[16] But it was not only Australia. The ELDO Secretary General, Count Carrobio di Carrobio, sent generous congratulations from Paris. From the US came applause from top officials of both NASA and ARPA[17], and later from Secretary for Defense McNamara, Vice President Hubert Humphrey and from President Lyndon B. Johnson himself. Johnson added a poetic touch by saying that this latest addition to the growing list of Australia's firsts 'shines as brightly as the Southern Cross'.[18] Even the Soviet press acclaimed the launch, remarking that 'Australian scientists can be congratulated on a big success . . . Although WRESAT was developed by military specialists and put into orbit by a military rocket, we regard its launching as a contribution to the peaceful exploration of outer space'.[19]

Australian Prime Minister Harold Holt: 'a notable scientific achievement'. (PA)

In February 1968 the Planar Award for that year was presented to the Department of Supply and to Adelaide University for the WRESAT project.[20] This award was given by Fairchild Australia to mark outstanding achievements in the Australian electronics industry. At the very lavish reception in Adelaide, Fairchild's managing director, J. S. Baldwin, presented the Award to Minister Henty, expressing confidence that the WRESAT success was the beginning of a spurt in space activity—and governmental orders—for the Australian electronics industry. His confidence was misplaced.

The following April, a WRESAT display prepared by WRE Illustrations section was given pride of place in a comprehensive space technology exhibition, which was staged in the King's Hall of Parliament House, Canberra, and attended by about ten thousand people. During that year the display was also shown in other Australian capital cities, in the London Trade Fair and in a United Nations conference on outer space in Vienna.[21]



The exultant leading players (*from left*): Barnsley, Carver, Rofe and Woods, and the WRESAT display model.

Inevitably the euphoria over WRESAT faded away over the following year or so. Nowadays few people not actively involved at the time remember it at all. But those who took part look back on WRESAT with affection, and many would see the launch as WRE's finest hour.

EXPERIMENTAL FINDINGS

The vast quantities of data recorded on magnetic tape by the STADAN and other stations were sent by air to WRE. Here they were fed into the comprehensive data- processing system and slowly digested. To the joy of the experimenters most of the instruments had worked properly, though something went wrong with the ozone sensor (probably a cracked lens or leaking seal) and it produced uninterpretable data. It did prove possible to determine the attitude of WRESAT with a fair degree of accuracy using the magnetometer and a single optical sensor (one failed after launch), but it was a very laborious task and it is doubtful if the results were worth the effort.

The data reduction took some months and it was even longer before the University researchers and their WRE colleagues had finally analysed it all. The results were eventually published in three papers and formed the subject of a doctoral thesis, and they were also presented at meetings of the Committee on Space Research (COSPAR), In August 1968 Twiss presented a paper at the UN Conference on the Peaceful Uses of Outer Space in Vienna. Twiss's paper detailed the advantages of a special rocket-satellite experiment carried out while WRESAT was in orbit. On 2 December, three days after the WRESAT launch, a Skylark fitted with the same solar sensors had been sent up from Woomera. It gathered data on solar radiation and ionospheric conditions in the mesosphere, about 100 kilometres up, compared to WRESAT's perigee of 169 kilometres, which took it down into the lower chromosphere. The results complemented those from WRESAT, and they also checked their accuracy, giving confidence that the instrumentation in the satellite was doing its job properly. They revealed the presence of a 'shelf of ozone at a constant density in a narrow band 110-120 kilometres high, which confirmed and added to findings elsewhere. WRESAT observed no solar flares in the ultraviolet during its short life. The figure it obtained for the minimum temperature of the sun's atmosphere refined the previous data and later proved to be very close to the figure now generally accepted by solar physicists.

In August-September 1970, nearly three years after the launch, Rofe organised a WRESAT and upper atmosphere research conference in Adelaide. Three days of the conference were given over to WRESAT's objectives, design and findings, as part of an evaluation of the whole sounding rocket program which was now a decade old. Few of the papers were published, probably because Rofe left WRE soon afterwards. He died the following year, still only in his early fifties.

SIGNIFICANCE OF THE PROJECT

The value of WRESAT did not lie in the upper atmosphere experiments. The results here were, according to one informed but doubtless exaggerated and cynical opinion, 'not worth an old boot' as a permanent contribution to science. Rather, the visible success gave considerable kudos to WRE, which was to stand it in good stead in the difficult days ahead of agonising reappraisal during successive joint project renegotiations. After all, it was no mean achievement to develop a satellite package from the textbooks and launch it successfully within eleven months. This really was a remarkable feat, and Australian engineering can feel pride in it.

The project also greatly helped morale at WRE. All of those involved in WRESAT felt a great satisfaction in the successfully completed job, even if many wondered periodically if it could be done in the time. Further, so many worked together on the project that it acted as a considerable unifying influence. The WRESAT success was primarily one of team effort. Many small groups worked hard and long in close co-operation, and together they achieved something which many swore was impossible. It was commonplace for people to work on into the evening and to work at weekends and at home. Not all of the extra hours were rewarded by overtime payments. Never before or since at WRE have so many worked so hard for a single purpose, and the real credit for WRESAT must go to all of them.

In a way, WRESAT served as a kind of fire drill. It gave some idea of the speed with which WRE could plan and execute a task if an emergency military requirement ever came up. Perhaps more than anything, WRESAT demonstrated the ability of WRE's staff to attack a problem in a determined and efficient manner. It showed that the normal lengthy procedures can be streamlined if there is enough pressure to get results. This project had to be completed within fixed time limits which could not be extended under any circumstances, and this goal was achieved.

The real significance of WRESAT for the scientific historian is that it had no heirs. Despite its success and the proud words of the politicians which followed it, no government since has been disposed to put any more funds into an all-Australian 'space presence'. The brief fit of enthusiasm was over. After WRESAT, Woomera saw five more attempts at orbiting a satellite, but for each of them Australia reverted to its role of providing the Range facilities. And despite the temporary effect on morale at WRE, WRESAT came far too late to save Woomera from the long decline that was to be its fate over the following dozen years.

Notes and Sources

1. The idea of the 'space club' was very popular in the media at the time, but as far as the author is aware it never had a precise set of rules for membership. Until the 1967 WRESAT launching, only the USSR, USA and France had successfully orbited satellites from their own territory. In addition Britain, Canada, Italy and one or two international groups had provided satellites that were launched by American rockets fired from US territory. If the rules for membership are strictly interpreted as launching one's own satellite from one's own territory using one's own launcher rocket, it is interesting to note that neither Britain nor Australia has ever become a member. Neither Redstone/WRESAT nor Black Arrow/Prospero met' all these criteria.
2. Probably it is vain to look for a single source to the WRESAT idea. The late Jeff Heinrich used to recount how, during a routine flight to Woomera, a member of the Sparta team had told him proudly that the vehicle had orbital capability. John Rodger, now of TTS Division of the Advanced Engineering Laboratory, also noted this while doing calculations for the safety requirements.
3. Reminiscence of Peter Twiss in September 1983.

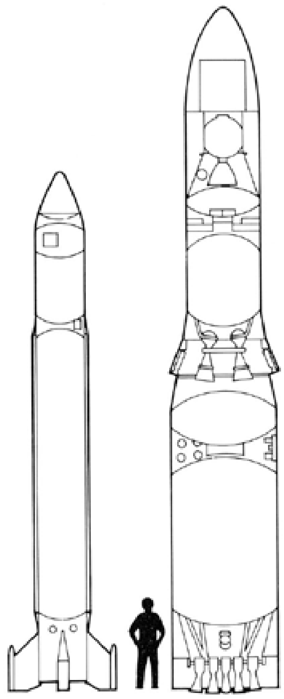
4. This is the subjective impression of one of the key players. Carver himself has commented that 'there was never a thought of failure. I strongly backed the project and can never recall having been cautious about it as is implied,' and his recollection is supported by Twiss also. Letters of 24 June 1985 and 10 February 1987.
5. 'Satellite builder', News (Adelaide), 1 December 1967. It is only too easy to overlook the role of the technicians both at WRE and at Adelaide University. Quite simply, they built the devices and got them working. It is impossible to ascertain all their names, but two who are easily remembered are Bob Hum and Alan Siskin.
6. WRESAT, WRE, Adelaide, November 1967.
7. WRE *Annual Report* 1967-68.
8. WRE *Annual Report* 1968-69, p.8.
9. Reminiscence of P. H. O. Pearson in a contribution of 1982.
10. Reminiscence of Dr Ewen MacKenzie of Adelaide University in August 1983.
11. 'Project WRESAT'. WRE Trials Instruction No. AS1 dated November 1967.
12. Contribution of Lance Anderson in June 1982.
13. Reminiscence of Brian Horton in an interview of 28 May 1985. As a scientist, Horton saw the decision in scientific terms but, as Barnsley has noted, there were other vital considerations: 'we will never know how conservative our decision really was but a failure to achieve orbit on account of such factors was to be avoided at all costs as by that late stage national prestige (and some heads) were at stake!' Letter of 18 July 1985.
14. '$5 fault causes failure in rocket', *Sun* Melbourne, 29 November 1967.
15. The reports and other conversations on the NASA 'SCAMA' net during the WRESAT launching and first orbit are preserved on a tape recording presented to WRE by NASA.
16. 'Australia's big day in space', *Advertiser*, 30 November 1967.
17. 'Rocket shot from WRE', *Advertiser*, 1 December 1967.
18. 'LBJ bouquet on rocket', Sun (Melbourne) 9 December 1967.
19. 'Russia hails WRESAT', *Advertiser*, 29 December 1967, reporting on an item in 'the latest issue of the Soviet Embassy newsletter in Canberra' which quoted an article by the science correspondent of the Novosti Press Agency, Yury Marinin.
20. 'Award given for WRESAT', *Advertiser*, 24 February 1968.
21. 'Canberra liked WRESAT display', SCODOS (staff magazine of Central Office, Department of Supply) June/July 1968, 37.

25 Black Arrow: *Britain's Own Satellite Launcher*

OVERVIEW

As we have seen earlier, Britain's rocket engineers and politicians began to look at the feasibility of a national satellite launching program as early as 1957, when the first Russian sputnik was circling the earth and Black Knight had hardly begun its ten-year career. Over the following few years the idea waxed and waned in popularity. Britain's role after April 1962 as the most senior of the six ELDO partners seemed at first to render superfluous a national launcher, or at least to reduce its urgency. But as the delays mounted and the limitations of the Europa vehicle became more apparent, and as other countries—notably France—pursued their independent space plans with vigour and success, the notion revived and finally in 1964 received enough governmental backing for development to begin. For several reasons the development of Britain's own satellite launcher, Black Arrow, was long delayed and it did not begin its three-year firing program at Woomera under the joint project until 1969, when ELDO was on the point of leaving Australia.

For economy and reliability Black Arrow relied heavily on the proven technology of its precursor, Black Knight. It used the same form of construction, the same propellants with uprated versions of the same engine, and many similar control and radio systems. However, with its three stages it was a considerably larger and more powerful rocket. Standing 13 metres high it was a third as tall again as the early Black Knights, and twice as wide at the base. Joined now by specialist newcomers, the organisations and teams which had produced and launched Black Knight continued their work; as far as the latter were concerned it was a natural extension of the program. The test site at Highdown and Launch Area 5 at Woomera were adapted and enlarged for Black Arrow but continued to be the centres of activity. Extra facilities had to be provided at the rangehead and new tracking stations built far out along a new direction of launch.



Britain's satellite launching vehicle Black Arrow (*right*) was a natural successor to the smaller Black Knight (*left*).

In 1969-70 three Black Arrows flew with varying success as part of a series to prove the system performance. Then in October 1971 a fourth Black Arrow lifted off from Woomera taking the operational satellite Prospero into a perfect orbit. At this high point of achievement the project was suddenly cancelled. The ground installations were dismantled and the design and trial teams quickly dispersed. Only Prospero, named for the magician of *The Tempest*[1], remains in space as a tribute to their efforts; it circles the earth every hundred minutes and unless tampered with will continue to do so for a century to come.

BLACK PRINCE: SHORT-LIVED CONTENDER FOR ORBITAL GLORY

The Black Arrow story really starts in the later years of the 1950s, which was a time of great ferment in British space technology. Amid a great number of wild and woolly schemes—talk of a 'pyramid glider' to take two men into orbit atop a 150-tonne rocket, for example—a few more sober-minded engineers were fingering their slide rules and wondering whether Blue Streak and Black Knight could be turned to the purpose of an orbital launcher. In fact neither rocket had got beyond its design phase when it was first demonstrated theoretically that a combination of the two was capable of putting a weighty payload into space. At RAE

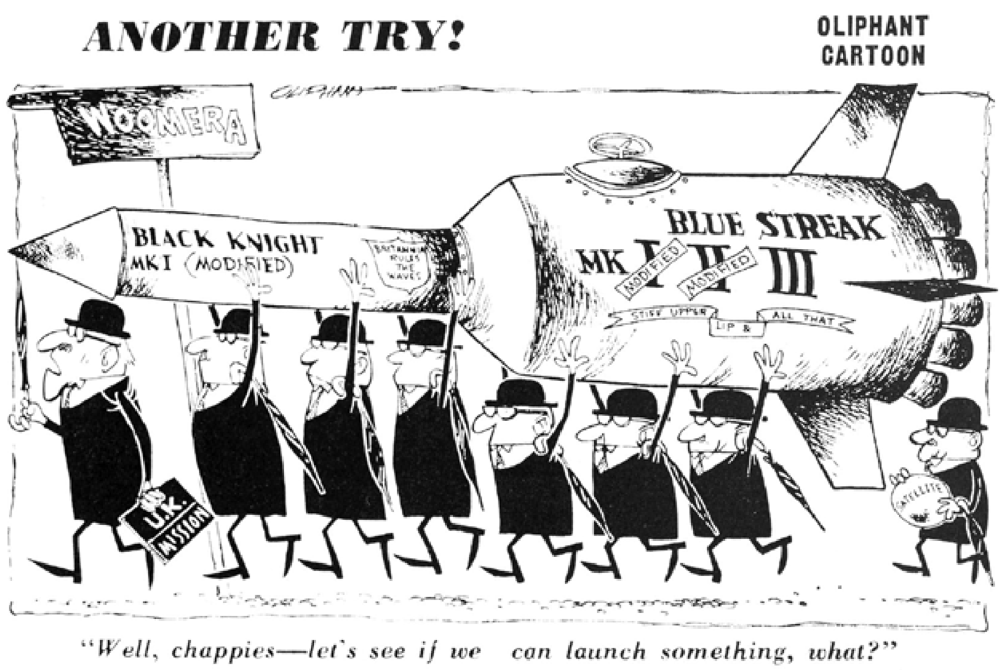
Desmond King-Hele of RAE Space Department.(RAE)

was working a brilliant mathematician, Desmond King-Hele, who later became a Fellow of the Royal Society and is also a literary critic, poet and biographer of the eighteenth century universal- man Erasmus Darwin. In 1957, the year of the tiny Sputnik I, King-Hele showed that these two rockets could, if coupled together, give enough power to project a satellite of 1 tonne into a circular orbit. Building on this idea, Geoffrey Pardoe of De Havilland suggested to the Commonwealth Spaceflight Symposium in August 1959 that the long thin Black Knight could best be modified to its position on top of Blue Streak if its propellant tanks were compressed into a doughnut shape so that it was not only much shorter but was swollen out to match Blue Streak's diameter.[2] The proposal looked drastic, even bizarre, but actually it involved no radical changes except to the tanks and none at all to the engines.

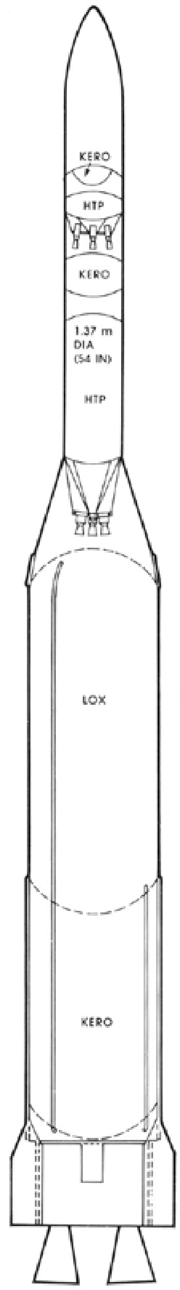
After the Blue Streak cancellation in April 1960 the concept of an entirely British launcher was taken up enthusiastically by the Guided Weapons Department at RAE, and it came up with a slightly different but more detailed design.[3] Dubbed Black Prince, it was to have three propulsion stages. A Blue Streak first stage would be surmounted by an enlarged Black Knight, and above the two would be a liquid hydrogen propellant third stage as yet undesigned, to bear the satellite into orbit. Had it been built, Black Prince would have stood 28 metres high and had a take-off weight of 94 tonnes. Its payload of 680 kilograms could have been placed into a circular orbit 550 kilometres above the earth; more than ample for the planned scientific experiments.

The joint project's Australian representative in London at that time was Horrie Higgs, the energetic man who had earlier distinguished himself in planning the facilities for Black Knight at Woomera. In May 1960 Higgs returned to WRE and over ten days conducted a seminar attended by fifty senior staff at which every facet of the Black Prince proposal was examined. Planning was in fact already well advanced. Both Area 5 and Area 6—the sites of the Black Knight and new Blue Streak launcher respectively—would be used for the launch preparations, and a satellite tracking station would have to be built far beyond Australia's shores in the Caroline or Manus Islands. One great novelty of the proposal was that the firing direction should be northerly from Woomera, so that the satellite could be injected into a polar orbit. This naturally posed a great number of problems for the safety authorities. The first burnt-out stage would fall into the cattle country of the Barkly Tableland between Tennant Creek and Camooweal and the second into the sea north of New Guinea. The rocket would be passing over the densely populated countries to the north of Australia; countries whose governments might not be favourably disposed to the enterprise.

A month later, in lune 1960, formal notice of the Black Prince project was placed before the CUKAC meeting in London.[4] The CUKAC chairman, Sir Steuart Mitchell, emphasised



This is how Adelaide *Advertiser* cartoonist Oliphant saw Britain's space aspirations at the time. (Adv and Oliphant) that the British Cabinet had not yet approved the project, but it would, he said, make a decision by the end of July. This would allow a schedule of eight developmental firings by 1964. Unfortunately the decision did not come; it was repeatedly deferred. Despite the delay, the engineers' enthusiasm for Black Prince ran high for some months. It was an inspiring sort of project with which it was easy to identify, for satellites and their launchers still had the charm of novelty and their possibilities seemed unlimited. With the assistance of the Black Knight contractors Saunders-Roe and Bristol Siddeley Engines, the RAE engineers took the design work close to completion. For their part the Australians had a hard look at the proposed flight corridor and impact zones by making a survey overland to the far north of the continent.[5] But by the end of 1960 little more could be done. WRE Deputy Controller Arthur Wills was obliged to point out that the Establishment now required some indication that Black Prince did indeed have a future.[6] In the first months of 1961 it became evident that in fact it had none. Britain had been dragging its heels over Black Prince because its negotiations with its European neighbours over forming a launcher consortium were still in embryo. Having received the report that Black Prince was feasible, the Cabinet had perceived that Britain had three options; to go into satellite launchers alone using Black Prince; to concentrate on the technology of satellites alone and rely on American launchers; or to look for partners to join it in a more ambitious satellite program. At the time the Cabinet ruled out the first option on the grounds that the cost of a powerful British launcher was beyond the nation's resources. The second option was judged unpalatable for several reasons. The last one was the path chosen and it led, as we know, to ELDO. With that decision Black Prince quietly vanished from the scene. The planning that had been put into it was by no means wasted. Britain's French and German partners in ELDO inherited some of the work and in general it left behind a valuable legacy of problems exposed and partly solved which were of benefit to the designers of Black Arrow.



Black Prince, an early British proposal for a satellite launcher, was to use Blue Streak as a first stage and a modified Black Knight as a second stage.

THE INCEPTION OF BLACK ARROW

In January 1962 the Guided Weapons Department at RAE was restructured under the title of Space Department, which better reflected its new concerns. Guided weapons work was now hived off to other departments, while Space concentrated solely on satellites and launch vehicles. Of the five divisions of the new Department, two were busily engaged with Black Knight's Dazzle program and the forthcoming Europa trials, but nevertheless the idea of a national satellite launcher rocket was not allowed to rest for long. Harold Robinson—that boyishly cheerful veteran of the whole Black Knight program—was officially encouraged to pursue an earlier idea which had emerged from the success of Black Knight. The work of Robinson and his colleagues was published towards the end of 1963 in the form of a draft project study[7] which delineated all the essential elements of what became Black Arrow. It described how the existing Black Knight techniques and equipment could be developed into an economical launcher system capable of placing a payload of up to 90 kilograms into an orbit near the earth. This payload was of course tiny by comparison with Europa's or Black Prince's, but it was large enough to cope with the most urgent research work: examining the durability of materials in space, evolving communications systems, testing the propulsion and guidance of launcher rockets and so forth. The exploitation of space was then practically a virgin field; valuable work might be done anywhere. A small launcher rocket could meet these scientific research needs relatively cheaply. Later on it might be used for the testing of orbital military reconnaissance equipment. The last mentioned use certainly did not exhaust the service interest in satellites at the time. An Air Marshal, Sir Edouard Grundy, drew up a shopping list:

> the UK military policy is clear and we are sure of what we want and their priorities, i.e. first a reconnaissance satellite, second, communications, third, interception and IFF, and fourth an offensive military satellite.[8]

Such were the grand, indeed rather grandiose, notions of what might be expected of a national satellite industry. At least this time the services could not be accused, as they so often have been, of preparing to fight the last war but one.

Saunders-Roe (by this time a division of Westland Aircraft) had been closely involved in the design study together with Bristol Siddeley Engines. They contributed a detailed scheme[9] of the complete three stage rocket, the first and second stages clearly being enlarged derivatives of Black Knight powered by extended versions of the familiar HTP-kerosene Gamma engine. The upper stage was a solid fuel motor on which the satellite was mounted. In size, the rocket with its 13 metre length appeared miniature compared with Europa; its first stage diameter of 2 metres tapered off to a 1.37 metre diameter second stage—identical in fact to the 54 inches originally proposed for Black Prince.

The following year, 1964, was a period of intense activity for joint project space operations. The first two Europa rockets were launched and the Dazzle program was well under way. At the same time, WRE was receiving a flow of detail on two separate proposals for future work. One was the British 'small satellite launcher' (not yet named Black Arrow); the other was the Crusade project, aimed at an extended Dazzle series using a larger Black Knight with the ubiquitous 54-inch diameter. For much of the year the two new schemes were developed almost in competition; but, as was explained in Chapter 21, Crusade was finally abandoned in favour of the more ambitious satellite launcher. Australia was officially informed of the decision in September, when the British representatives explained that the small satellite launcher was 'essentially a research facility, not directed towards any specific military objective but towards putting the United Kingdom firmly into satellite technology'.[10] RAE hoped to prove the rocket with five trials up to January 1968, after which the practical program could begin.

All that was needed now was governmental approval to proceed. The reasoning behind the project seemed eminently sound to the engineers of RAE. Sir Morien Morgan, Director of the Establishment, put it eloquently in his Report to the Select Committee (1970-71):

Sir Morien Morgan, Director of RAE Farnborough, in 1969. (RAE).

> I regard these small launchers in much the same way as I regard wind tunnels or simulators, as an essential part of the trade . . . I do not really believe that enormous launchers on which you might occasionally cadge a lift and do a little experiment will ever completely stop the need for these quite small payload and relatively cheap launchers.

Approval was, however, painfully slow in coming, for reasons not apparent to the Australians. In January 1965 a small allocation of funds let work proceed on a 'minimal' basis, which meant only three-monthly fundings for the principal contractors, Westland, Bristol Siddeley and Ferranti. There was no provision for satellite design work except for that done by RAE. Despite these restrictions the developmental work did make good progress, although it was obvious that the launching program would inevitably be delayed. In fact the project remained in limbo, 'under review', for the next two years. It seemed for a while that the estimated cost of eight to ten million pounds was too expensive, and that Black Arrow was destined to be erased from the drawing board like Black Prince. What apparently swung the balance in favour was RAE's proposal at the end of 1966 to reduce the proving stage of the program by cutting down these trials from five flights to three. At long last, in December 1966, Minister of Aviation F. W. Mulley announced that Black Arrow would go ahead as part of Britain's national space effort. Perhaps a spur to action had been the news the previous month that the French had put a 43 kilogram satellite into orbit with their Diamant rocket—a wholly indigenous product from top to bottom. Be that as it may, as so often before in the history of the joint project, Britain no sooner came to a decision after much irresolution than it expected its partner to move things along swiftly. The brisk new proposal was for a first development firing in June 1968 and the two subsequent ones at six-monthly intervals. Not unnaturally WRE Director Don Woods was quick to point out that this meant slashing the preparation time by three months even though the question of the Australian financial contribution had yet to be settled and the new impact zones outside the Range boundaries would require Cabinet approval.[11] To get things under way at Woomera he recommended that $100 000 should be forthcoming at once from the British Treasury, pending joint project agreement.

The money came through within the month and thenceforward events in Australia progressed with remarkable speed. By June 1967 the estimated cost to the joint project of three Black Arrow development firings—$1 327 000—had been approved. The sensitive question of the new zones of impact took rather longer to resolve. The Cabinet gave its conditional approval in October; and after an exchange of letters[12] between Prime Minister Gorton and two successive Premiers of South Australia, Don Dunstan and Steele Hall, formal approval came in May 1968. The decision was marked by none of the fierce controversy of twenty years earlier. The public was now more blasé about the Range and rockets overhead, and the perfect safety record encouraged it to be so.

During the long period of uncertainty when it was unclear whether Black Arrow would ever proceed, joint planning between the two countries had been unceasing. The first British technical mission arrived at WRE in March 1965, headed by Harold Robinson of RAE with a team of nine members from Space Department and Westland Aircraft. In a hectic series of brainstorming sessions lasting a fortnight and involving at least forty WRE and contractors' staff, the design of Black Arrow and its supporting installations at the Range was worked through. Questions of flight safety featured prominently on the agenda, prefiguring the problems that were to arise later.[13] By May 1966, when the second mission arrived led by Leslie Parkin (the engine enthusiast who was now the UK Project Officer), WRE had prepared a planning specification setting out what exactly would be needed for the launchings. The first estimates of cost came out of these discussions; and when the funds became available in the following year, work at the Range started at once. By this time, early in 1967, the first prototype Black Arrow had been built and was under test in Britain.

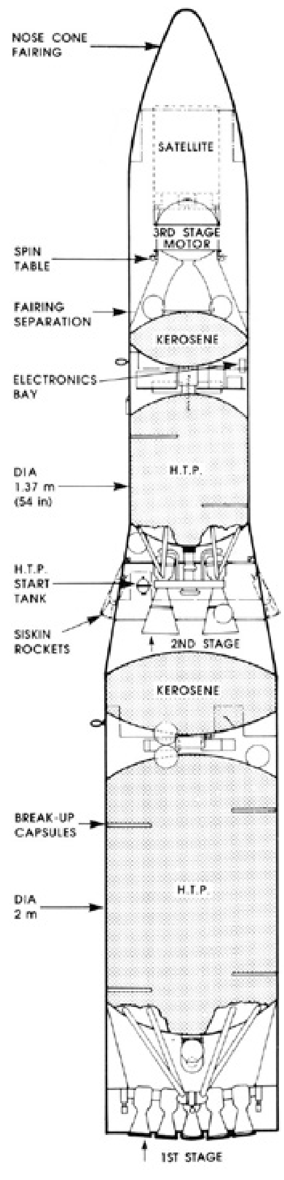
DESIGN AND PERFORMANCE

Although Black Arrow was based on the engineering of Black Knight, it had a very different task to perform. Black Knight climbed and fell almost vertically to give it the greatest possible re-entry speed, and it could land well inside the Range area. Black Arrow had to carry its satellite payload up and away on a gradually curving ascent until, almost ten minutes after lift-off and at 1700 kilometres from Woomera, its upper stage would be flying parallel to the earth's surface at a height of 560 kilometres. At this point, with its speed approaching 8 kilometres a second, the satellite would be released into permanent orbit.

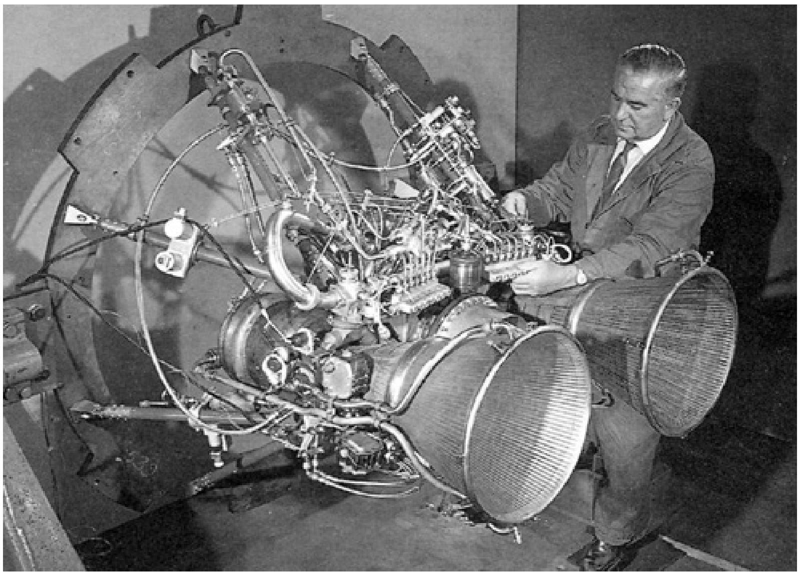
To achieve this performance the rocket was constructed of three separate stages.[14] The first and second stages were effectively enlarged versions of Black Knight, with more powerful engines burning the proven HTP-kerosene mix. The third stage had a specially designed slow-burning and lightweight solid fuel motor. Above this sat the satellite under a protective nose cone. The complete Black Arrow stood 13 metres tall and weighed at take-off about 18 tonnes.

Obviously a far more powerful engine than Black Knight's was needed to lift such a weight. We recall that the later Black Knights used an engine known as the Gamma 301, while Bristol Siddeley had already developed an updated version (304) in readiness for Crusade. The Gamma 304 had four combustion chambers. By doubling the number of chambers in a yet more powerful design called Gamma 8, an adequate thrust of 22 700 kilogram weight was possible. The eight chambers of Gamma 8 were arranged in four groups of two. Each pair was fixed together on a radial trunnion axis able to swivel to and fro (as did the single chambers of Black Knight) and thereby steer the pitch, yaw and roll of the rocket. The whole assembly with its turbines, pumps and control apparatus fitted neatly into an engine bay at the base of the 2 metre diameter first stage. Above it were the two propellant tanks, separated by a small compartment containing electronics and other flight equipment, while the uppermost section tapered off to match the diameter of the second stage.

As always with multi-stage rockets, the performance of Black Arrow depended in large part on the efficiency with which it discarded each stage as soon as its job was done. The first stage took the complete rocket up to 50 kilometres, the fringe of the atmosphere, before its propellants were exhausted. At this point an inertia switch detected the lack of acceleration and the first stage was detached by explosive bolts, falling to earth. Immediately four Siskins[15]—small solid fuel motors at the base of the second stage—were ignited, producing a few seconds of thrust. This ensured that the liquid propellants settled at the bottom of their tanks where the engine inlet pipes were located. All was now ready for the second stage engine to light up. When they were on the ground Gamma engines were started by applying HTP under pressure from an external tank to the turbines, which, once running, pumped propellants from the main rocket tanks both to themselves and to the engine chambers. The second stage of Black Arrow had to carry a small starting tank of HTP, pressurised from a nitrogen gas bottle. These components were fitted in the lower tapered



The three stage configuration of Black Arrow.



Above right: The Bristol- Siddeley Gamma 8 rocket engine.

Above: The Gamma 2 used in the second stage. (Rolls-Royce)

section—the interstage bay—and they came into action as the first stage dropped away. The engine ignited and second stage flight began. Having done its job the starting apparatus was detached with the interstage bay and followed the first stage to earth.

The second stage engine, known as Gamma 2, was also based on the Gamma 304 design but in this case only two chambers were necessary to give the desired thrust. The drawback was that having the chambers swivelling about a single axis was insufficient to steer the rocket; to do that, each chamber had to be free to tilt in any direction. The solution was to mount them on an intricate gimbal system. This permitted full movement while the propellants passed to the chambers via a cleverly designed hollow feed-through, obviating the need for a flexible coupling. Several other design changes were made to reduce weight and improve efficiency. The hydraulic actuators, for instance, used kerosene from the main fuel pump as a working fluid instead of oil. The engine performance was also improved by extending the flared chamber nozzles to suit the free space conditions of second stage flight, giving a total thrust of 6940 kilogram weight. The second stage construction followed the usual pattern with the two propellant tanks forming the body of the rocket, separated by a pressure tight compartment for the flight instrumentation. The compartment contained Black Arrow's brain, which guided it up to orbit and controlled the timing of each operation up to the point when the third stage separated.

With the first stage discarded, the rocket had lost more than three-quarters of its mass and was half its original length. The Gamma 2 engine continued to thrust it on its upward path, at an increasing acceleration as the propellants were consumed. At a height of 90 kilometres, which is practically in space, the two halves of the nose cone protecting the satellite were divided by separation springs so that they opened outwards and fell away.

Some four minutes after launch, at a height of 200 kilometres, the second stage was exhausted. Now more than 350 kilometres down-range from Woomera and travelling at about 5 kilometres per second, Black Arrow was no longer accelerating; but its inertia took it upwards on a long curving trajectory. This coasting period lasted for a further four and a half minutes, but the rocket was by no means quiescent during this time. Its guidance system continued to operate: although it was no longer necessary or possible to steer the rocket, it had to be lined up accurately parallel with the earth's surface, ready for the final injection into orbit. Eight small nozzles mounted at the base of the second stage emitted short bursts of high pressure nitrogen gas, controlled by the guidance system, to turn the whole rocket slowly into the required precise attitude.

The third stage motor and satellite were mounted at the top of the second stage on a spin table, a large circular bearing which allowed them to rotate about their central axis, lust before the end of the coasting period a group of small solid rockets around the base of the third stage began to spin it like a top at the rate of three revolutions per second. This stabilising spin ensured that the third stage and attached satellite maintained its precise attitude during the third stage burning after the control system and its nitrogen jets had fallen away.

The second stage had now completed its task. It too was detached and began its long fall to earth from a height of 530 kilometres, mostly burning up when it reached the denser atmosphere. All that now remained of Black Arrow was the spinning third stage about 2.5 metres long, carrying a telemetry package plus timing units to initiate the last few actions, since the main timing controller had already been detached with the second stage. Its motor was the Waxwing type, developed at Westcott with many novel features. The extremely thin motor casing, no thicker than a plastic credit card, was a sphere of immensely strong maraging steel—machine tool grade steel tempered by a special process. From this casing protruded a large bell-shaped nozzle. The propellant consisted of a type of plastic explosive with its rate of burning controlled by adding a small proportion of aluminium. The satellite itself, in front of the motor, had a different shape and design in each trial and will be described shortly.

The Waxwing motor ignited thirteen seconds after the second stage separated. It burnt for forty seconds with a powerful thrust which added an extra 3.3 kilometres per second to its speed and took it into orbit. Then it too was jettisoned. The still spinning satellite remained in orbit with its own power supply and radio apparatus. At a gradually widening distance, the burnt-out Waxwing and third stage residue accompanied the satellite as earth-circling items of space junk.

FLIGHT CONTROLS AND INSTRUMENTATION

It will be recalled from Chapter 21 that Black Knight was controlled by two independent but complementary systems: firstly, by its internal gyroscopic autopilot; and secondly by its riding up a fixed radar beam with the necessary small corrections in heading being passed to it by radio. Such a system served Black Knight well enough, with its almost vertical 'straight up and down' trajectory; but Black Arrow required something more sophisticated. As we have seen, its flight path took it outwards from the launch area along a gradually ascending curve. Such a trajectory could not be marked out by a fixed radar beam, and in any case the rocket's two stages would take it too far away for reliable radio control. But most important, the attitude of the third stage had to be precisely set at the moment when the satellite entered orbit.

The solution was to replace Black Knight's relatively simple gyroscopes with a far more complex Attitude Reference Unit (ARU), which was capable of controlling the orientation of Black Arrow with great accuracy and rendered a ground-based guidance system unnecessary. It fitted into the second stage electronics compartment along with the rest of the rocket's brain.

The ARU was manufactured in Edinburgh by Ferranti, a firm which had built gyroscopic systems of many types including navigational devices for aircraft. The ARU was actually a high precision inertial navigation system housed in a sealed, gas- filled container. Its heart was a cluster of four concentric gimbals.[16] Inside the innermost gimbal was mounted a stable platform which, controlled by three gyroscopes (one in each plane), maintained a fixed attitude in space no matter how the external framework turned.

The orientation of the stable platform was initially set before launch, and dictated the attitude of the rocket throughout its flight. If any misalignment developed between the two, a small electrical signal from the ARU would cause the appropriate combustion chambers to move and provide the necessary corrective thrust. We see that the general principle of operation was the same as Black Knight's, but, difficult as the requirements were in that case, they were immensely greater for Black Arrow. There were effectively three separate configurations to be controlled in turn: the complete rocket after launch; the upper stages after the first stage had separated; and finally, the coasting period when the attitude was adjusted by nitrogen jets in the second stage. The three conditions were totally different and required three different sets of controlling conditions which had to come into play sequentially. The full system needed five gyroscopes in addition to those in the ARU.

Since its stable platform governed the heading angle of Black Arrow, the ARU had control over the rocket's trajectory. After launch, in an operation known as platform torquing, the platform was slowly rotated away from its original setting for a vertical take-off. After a few seconds of vertical flight to clear the gantry, the platform was torqued so as to tilt the flight heading about 3 degrees down-range. As the flight continued, torquing was used again until at first stage separation Black Arrow was flying at a shallow angle of less than 40 degrees to the earth's surface, still ascending but also moving rapidly down-range. During the second stage flight and coasting two further periods of torquing finally produced a third stage which was travelling almost horizontally in the correct attitude for injection into orbit.

The timing of these operations was controlled by an automatic timer known as the flight sequence programmer, which was fitted beside the ARU in the second stage instrumentation compartment. This was a high precision mechanical device, purpose-built at RAE, consisting essentially of a set of rotating cams driven by a crystal-controlled electric motor. It was switched on and checked during the final countdown, and its first timing sequence began a few seconds before launch. As the flight continued, separate timing sections and switches came into action when each stage was exhausted. Apart from the ARU torquing periods, the programmer also controlled many other events such as the separation of the stages, the time of ignition of the upper stage motors and various flight safety actions.

ON-BOARD TRACKING, TELEMETRY AND SAFETY

During its flight Black Arrow was tracked by several ground radars, each requiring its own special type of transponder in the rocket. In the first stage was fitted a transponder which, in conjunction with the doppler radars at the Range, charted the trajectory of the stage on the ascent and, after it had separated, down to impact. The second stage, fitted with a C-band transponder, was tracked by the FPS-16 radars as soon as it rose into their line of sight, and thence as far into the distance as the strength of the signal transmissions permitted. In the third stage of a later vehicle was an L-band transponder, developed in Belgium for ELDO's Europa. It operated in conjunction with the distant tracking station at Gove to provide a very accurate record of the third stage trajectory, including the point where the satellite was released.

Each of the three Black Arrow stages also contained its own telemetry transmitter, sending back a wealth of information to the receiving stations on the Range. Each transmitter sent many channels of coded information sequentially, the exact number depending on how many times a second one wished to take samples from the source sensors. In one trial no fewer than 136 separate sources of information were obtained from the first stage, covering every detail of the rocket's motion and attitude, the engine and control system performance, the transponder operation and numerous in-flight temperatures and pressures at selected points. Much information was telemetered from the other stages too, although in the case of the third stage, where it was vital to know precisely the acceleration and attitude at the time of injection into orbit, the number of data channels derived from accelerometers, gyroscopes and certain experimental sensors was reduced to twenty-four to allow the rapid sampling rate of eighty times per second. For the last firing of the series, the telemetry sender of the satellite itself was programmed to transmit this important injection information. Finally, a fourth telemetry transmitter was specifically designed to measure vibration in flight. It could be placed as required: initially in the second stage where the sensitive ARU was mounted, and later in the third stage to check vibration conditions which might affect the satellite.

As with all the long distance rockets fired at Woomera, the flights of Black Arrow were as safe as human ingenuity could make them and were planned in cooperation with the WRE Safety Authority, headed by Lt Col George Foreshew, the meticulous Chief Safety Officer whose genial manner belied his complete imperviousness to any suggestion that safety standards might be relaxed.

Black Arrow used WREBUS, designed for Blue Streak and perfected in the ELDO trials, which transmitted its radio signals from two ground stations to two receivers in the vehicle's second stage. For much of the second stage flight the rocket was switched to the 'fail-destruct' mode, so that the WREBUS signals had to be received constantly to avoid self-destruction. If it was triggered, the destruct system first closed down the engine to prevent the fragments dispersing widely and then seconds later the oxidant tanks were ruptured by injecting manganese dioxide into the HTP as in Black Knight.[17] The many other explosive devices were separately destroyed. The third stage solid fuel motor was ignited and the end of the casing severed by an explosive cutting charge so that all the propellant burnt away without developing any thrust. The guiding principle was that even in a normal flight no explosive material should return to earth, and this included the break-up capsules themselves which of course in normal flight were not used. A timing circuit initiated by the flight sequence programmer fired them off as the jettisoned parts descended. Even the third stage was automatically destroyed in the event of a premature separation.

Each of the radio systems described above had its own frequency and its own aerial, not to mention the satellite itself which had a separate telemetry and telecommand system to be used during its expected long life in orbit. Black Arrow bristled with aerials: there were fourteen on the later vehicles and each one needed a long session of design testing (usually employing a scaled-down model of the rocket) to ensure that its radio signals were correctly beamed to the correct ground station. The risk was high of one signal interfering with another, and the problem was overcome only by very careful initial design and then by rigorous practical testing at Highdown and Woomera.

NEW FACILITIES FOR BLACK ARROW

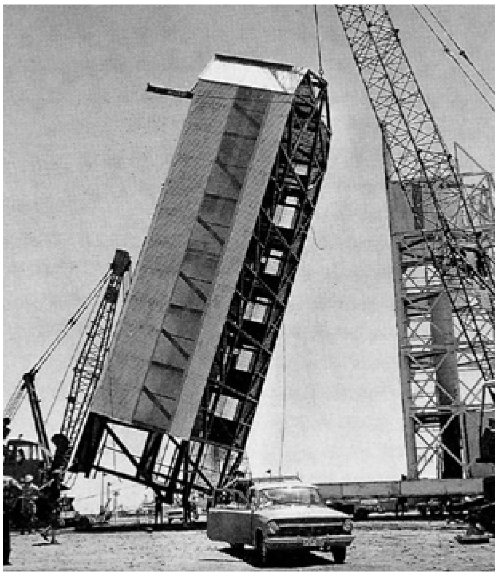
Throughout 1966 the planning and design of Black Arrow went forward in Britain and the requirements were passed on to WRE. The policy was to make full use of the Black Knight equipment by modifying what already existed. New tracking and telemetry stations would have to be set up distant from Woomera. The latter facilities will be discussed shortly.

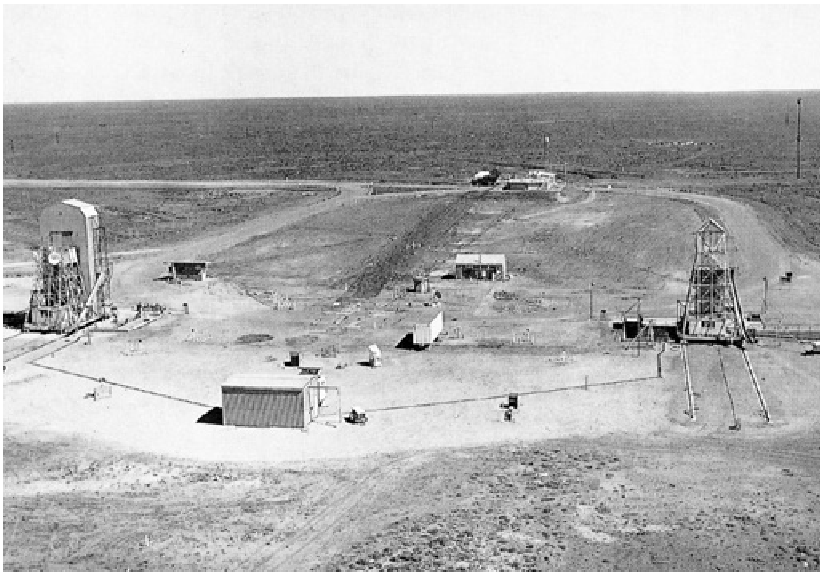
The first Black Arrow co-ordination meeting in Australia was held in January 1967, and this marks the formal commencement of the program in Australia. At this meeting the date of the first launch was set for only eighteen months ahead, in June 1968. At Woomera the general work of overhaul and modification at the launch site, Area 5, included improving the high pressure gaseous nitrogen supplies and the storage and transport of propellants, and replacing the water plumbing which ran out from Range E. The concrete pad needed renewal as over the years it had moved and cracked, and this could be dangerous if drips of HTP collected there. The other new requirement was two cleanrooms for the satellite: one at the Test Shop and one on top of the gantry for the final installation.

Of the two launchers themselves, 5A was adapted to the purpose of testing and static-firing Black Arrow's second stage, while Launcher 5B was altered more drastically for first stage testing, assembly of the whole rocket and launching. Unfortunately, the Black Knight gantry towers were not compatible with Black Arrow: 5A had to be modified and 5B rebuilt entirely. Westland Aircraft supplied detailed instructions. The work on the launcher stand included provision of a new strong centre section with supporting struts fitted to existing legs which were to be shortened. It was to be lower than Black Knight's, with a larger and more robust release jack. The launcher was mounted on a large base ring so that alternative firing directions could be selected, and the whole assembly was to be capable of accepting the much higher loading of Black Arrow. The 5B gantry was much altered. A new box, one storey higher, replaced the old, with additional access stairs and emergency escape chute. The new upper level of the tower, in which the satellite was to be attached to the rocket,

Below: Area 5, the old Black Knight site used for Black Arrow. The rebuilt launcher 5B is on the left.

Below left: Lifting the new gantry into position.





was made as a cleanroom with internal walls and doors being dust sealed. The interior was fully air-conditioned and dust filtered. It had the pristine appearance of a hospital operating theatre. The new gantry was twice the weight of the old, but the axles and rails below were adequate. This time everything was manufactured in the Salisbury workshops, not sent out from Britain in kit form.

The modifications to Gantry 5A for checking and test-firing the Black Arrow second stage rockets were relatively simple. An adaptor pad was introduced to the launcher, incorporating the second to first stage rocket attachments so that the second stage could be erected in a manner similar to its final mounting on the first stage. Only the lower section of the gantry tower was used, almost unchanged.

At Highdown on the Isle of Wight much less reconstruction was done. Black Knight's two towers and supports were extended to allow the first and second stages to be tested separately. (The second stage had to be treated as a rocket in its own right and could not, of course, be test-fired when mounted on top of the first stage.) The satellite housing and a dummy third stage motor were checked for correct assembly at Highdown, followed later by a satellite model and a set of checkout equipment brought in an air-conditioned trailer.

Test Shop 2 ablaze.

THE TEST SHOP

During the two years of liaison and planning which followed the British mission of 1965, it was generally accepted that Black Arrow, like Black Knight before it, would be assembled and checked in Test Shop 2. This was not really spacious enough for the larger rocket, but matters were eased when WRE allocated the adjacent Test Shop 6 for work on the satellite. But all these formative plans were rudely disrupted on 10 April 1967, when a disastrous fire completely destroyed Test Shop 2. It originated in the air-conditioning ducts which were partly made of flammable caneite boarding. When the fire brigade investigated a show of smoke and partly dismantled the ducts, the sudden flow of air caused a flash ignition which set the whole roof ablaze. Then the fire-fighting water supply failed and nothing could be done to save the building or most of its contents.

At first the fire looked like a major catastrophe for Black Arrow. Much of the lost equipment was test gear, special tools and all kinds of beams and other materials waiting to be installed at Area 5. As a further blow, in the ashes the trials team found the debris of their Coke machine. The heat had been so intense that only a solidified pool of metal remained in the coin compartment. But in the end few of the team regretted the fire. After WRE made some heroic efforts to relocate staff and other projects including Ikara and Rapier, Black Arrow was allocated Test Shop 4. Here the team enjoyed a far more spacious setting, where there was ample room for all three stages to be worked on at the same time. Systems laboratories, offices, workshops and stores were to hand. One specialised requirement was the Attitude Reference Unit laboratory. This needed special air-conditioning and the construction of a rigid concrete plinth, stable in its position to within 20 seconds of arc, for mounting the unit during its preliminary checks. Another was the cleanroom where two satellites could be prepared simultaneously. Here the air was thoroughly cleaned and filtered.[18] The safeguards for extreme cleanliness were strict. They included an airlock with an air shower, giving an air blast and vacuum action to remove dust particles from the clothing of the operators before they entered. This facility, as well as a further annexe used as a control room, was completed with creditable speed in 1970 in readiness for the arrival of the first satellite.

STANDARD RANGE INSTRUMENTATION

Throughout the Black Knight program and the early Europa firings WRE had constantly extended the ground instrumentation at the Range, and Black Arrow inherited a refined and elaborate network of optical and electronic devices. The RAE and its contractors, eager to get as much as possible out of a small number of firings, were more than happy to see the full panoply of photographic and electronic tracking equipment at work. RAE's task was to present a list of desirable measurements that might be made from the ground with cameras and radars: such things as an accurate record of the trajectory of each rocket stage, of the velocity and acceleration at selected times, and of key events like the separation of the stages and the jettisoning of fairings. Some compromises were necessary, but broadly WRE agreed to provide the data and a draft planning specification was drawn up.[19] The existing equipment at the Range was mostly adequate. As will be described shortly, it was only for the distant part of the trajectory, far beyond the Range boundaries, that new installations were required.

The ground instrumentation proposed by WRE was extensive and as usual varied from trial to trial. However, the description which follows is typical of what was used during the Black Arrow program.

The optical instruments were several specialised types of cine camera. (Black Arrow was launched only in daylight.) The simplest cameras were those fixed around the launcher, three of the five being old 16 millimetre war surplus units. They were remotely controlled to capture the events of ignition and lift-off: they recorded the flame build-up and motion of the combustion chambers, the opening of the release jack, ejection of ground supply plugs and retraction of the wind braces. Five other fixed Vinten cameras were located about the launch area; one was even placed on the roof of the equipment centre. Their task was to photograph the first 30 metres or so of Black Arrow's ascent as it rose slowly from the launcher. They used a high film speed—100 frames per second—and their records enabled the rocket's initial ascent motion and acceleration to be accurately determined. Another seven cameras of a more sophisticated type were dispersed at posts along the Range up to a distance of 70 kilometres. These were servo-tracking Vinten and Rakimo cameras, whose operators manually tracked the course of the rocket. These cameras were able to discern at least part of the stage separation sequence. Up to nine Contraves kinetheodolites were also employed along the length of the Range to measure the rocket's trajectory.

The electronic tracking systems consisted of three radar stations, working in conjunction with the on-board transponders. The trajectory of the first stage was tracked and recorded by a doppler system, which was in fact a network of eight ground stations: one transmitter and seven receivers. Black Arrow's trajectory could be computed by comparing the seven recordings with each other.

The other two systems were the FPS-16 radars, which had been used in the later phases of the Black Knight program and in countless other trials at the Range. One was at Red Lake and one at Mirikata. Neither radar could 'see' the ascending Black Arrow until it rose over the horizon some thirty seconds to one minute after lift-off. But once locked on they continued tracking the rocket to about 1500 kilometres range, when reception faded away through distance and the tumbling motion of the separated second stage which carried the transponder. For all this time the radars passed back data to the Range's acquisition system and thence pointing directions out to all the camera posts which required them.

The telemetry transmissions from Black Arrow were received at the two principal ground stations already located at the rangehead and at Mirikata. Each station received and recorded the data arriving from the four separate senders in the rocket. Some difficulties were foreseen in receiving signals from the third stage nearly 1850 kilometres away, when the motor ignited and the payload entered orbit, and the only solution was two extra telemetry stations at chosen places down-range.

As always, a large part of the Range instrumentation was devoted to giving the Flight Safety Officer (FSO) the most reliable and up-to-date information possible on the course of the flight. Black Knight, we recall, used skyscreens and optical (MTS) trackers out on the Range, which passed their signals to impact predictors and plotted displays in the Instrumentation Building. This network was supplemented by outputs from the ground-based guidance system. But Black Arrow did not use ground guidance, and anyway it would quickly pass out of range of the MTS trackers. Hence, although the Black Knight system would serve for the early part of the flight, more instrumentation was obviously necessary. Fortunately WRE had already encountered and satisfactorily dealt with the same problem for the Europa trials, and the two FPS-16 radars and the DIP computer were available as before.

Thus the FSO was to be presented with information from several different sources, each covering a particular part of the trajectory, and as the flight progressed they came into use in sequence with a considerable amount of overlapping. Even before lift-off the FSO could watch the action at Area 5 on a television monitor, and when engine ignition occurred it was arranged that he would be informed of any abnormality in the developing thrust. Then as Black Arrow rose from the launcher, the operators at two skyscreens watched its ascent for any sideways deviation which might endanger the complex of Range buildings—in which case they would immediately transmit a warning.

After about half a minute, at a height of 1.5 kilometres, the rocket was already being tracked by four optical posts of the MTS system. The FSO would see the first displays drawn by moving pens on two large plotting tables: one showing the present position of the rocket and the other, computed by an analog impact predictor, indicating where the rocket would land if its propulsion suddenly failed (or if, for example, a break-up command was transmitted). The latter display point, normally moving well ahead of the 'present position', was known as the 'walking impact point', but if propulsion ceased the indicated point would of course stop walking and become stationary. The optical MTS was able to track Black Arrow up to a height of about 30 kilometres, by which time the two FPS-16 radars had taken over for the rest of the trackable flight. Three more plotted displays came into operation, showing the walking impact point now derived from the analog and digital predictors. In the later firings, the DIP performed a further computation which was called an 'extrapolation'. It calculated where the second stage would land if it were to fall short because of a poor performance by the first stage, and it showed that position on a sixth table. It gave the FSO more time to consider his response.

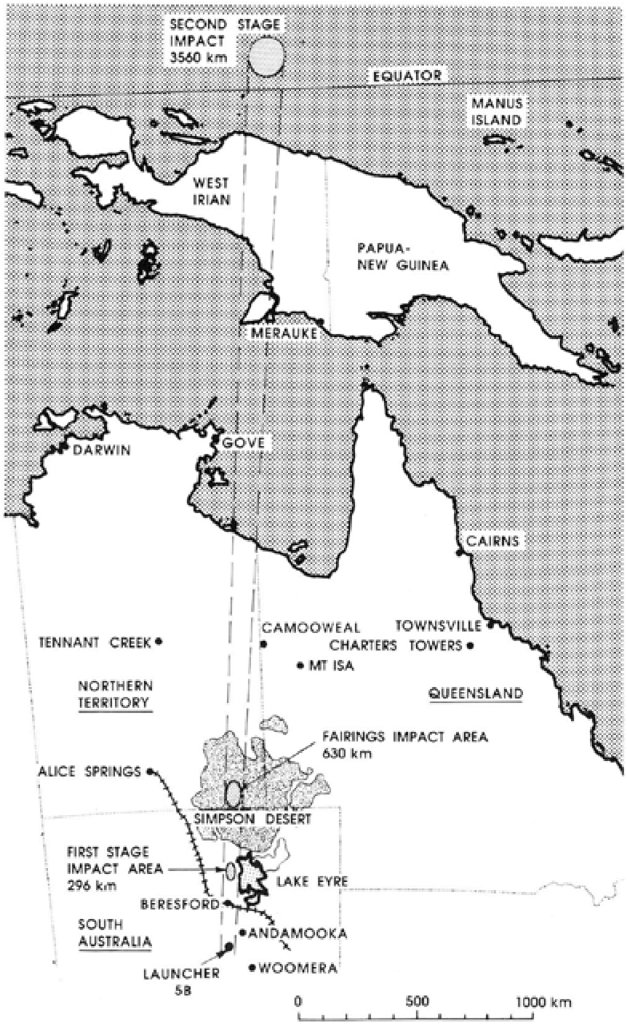
The completion of each flight trial brought a temporary period of relief for some members of the WRE staff and the trials team. For others it marked the start of hectic work in recovery and renovation duties, performance assessment and compilation of reports. In particular, Mary Whitehead of Planning and Data Analysis Group at Salisbury had the onerous task of organising the analysis, tabulation and plotting of the enormous quantity of film, tape and other records which had emanated from the ground instrumentation. She had a large team of assistants, but nevertheless the pressure was intense, since naturally everyone wished to see their records without delay.

NEW TRACKING AND TELEMETRY FACILITIES

By the time Black Arrow became a reality, the question of a firing direction for satellite launching rockets had been mostly resolved by WRE. The problem was, of course, that from the earliest days the proclaimed boundaries of the Range had been based on a north-westerly flight track over mostly uninhabited regions of Australia, to cross the coastline between Broome and Port Hedland. Like its predecessor, Europa, Black Arrow was intended to place its satellite into a near polar orbit, and so would have to be launched approximately north from Woomera. This would involve the overflying of less sparsely populated regions of Australia and countries further north, and the establishing of safe impact zones for those parts of the rocket which would be jettisoned during its long ascent. Obviously Black Arrow needed to have its technical performance guaranteed before such a flight could be undertaken.

The reduced program endorsed by both governments in May 1968 allowed for just three firings, of which only the first, designated R0, was to fly along the Range centre line. R1 and R2 were to be fired to the north, completing the development phase. R3 was to carry a sophisticated operational satellite, followed by many other 'spacecraft', as the payloads were generally known. This was the expectation, at least.[20]

R0 was to have an operational first and second stage, but a dummy third stage motor. Its payload would be spun and separated at the correct time and would carry instruments to check that it had done so, but naturally it would not achieve sufficient speed to go into orbit. Apart from that, all the flight and jettisoning actions would be put to the test. The



Above left: The northerly flight path for the later Black Arrow firings, including the final successful launch of a satellite into polar orbit. They used the ELDO tracking station at Gove, and special instrumentation sites at Andamooka and Charters Towers.

Above: Telemetry equipment at the Charter Towers airfield.

first stage and nose fairings would fall well within the Range boundaries at distances of 325 kilometres and 470 kilometres respectively from the launch point. The second stage, third stage and payload would continue their flight over the Great Sandy Desert and the Talgarno Prohibited Area until, at 3200 kilometres from Woomera, they would splash together into the Indian Ocean well to the south of Java.

Black Arrow's subsequent northerly flight paths lay a little east of north, so as to bypass population centres such as the towns of Camooweal, just within the Queensland border, and Merauke, in West Irian. The impact points were of course outside the Range boundaries. The first stage would fall on the north-west edge of Lake Eyre and the nose fairings in the Simpson Desert, while the second and third stages would pass over West Irian and the former splash into the ocean about 425 kilometres north of that country. The risk to lives and property in any of these areas was minuscule, but the full measure of WRE's safety precautions was nevertheless put in train.

Though the Range's instrumentation was by this time extremely comprehensive, more was needed. Black Arrow was the first—and, as it proved, the last—time that the joint project partners handled all of a satellite launch by themselves, and a great deal of information had to be garnered to make the most of it. The RAE engineers were especially keen to film the first stage separation and the jettisoning of the nose fairings. They wished to measure the gradually widening distance between the two stages to an accuracy of less than a metre until they were at least 45 metres apart, as well as determining whether the separation had occurred in a smooth straight line.[21] Supplying this information was an arduous task for WRE, considering that the events would occur some 50 to 90 kilometres up in the sky. It demanded tracking cameras of high magnification and resolution correctly positioned to photograph the rocket from two directions when it was brightly illumined by sunlight.

Locating the cameras suitably was straightforward for R0, the north-west firing. At a distance 70 kilometres down-range were two sites, V51 and V52, on either side of the line of flight. The cameras installed there were Rakimos with telephoto lenses. At first stage separation they would be looking upwards and slightly backwards from a position almost at right angles to the rocket's path. This was an ideal arrangement, providing the launching took place in the early morning when the sun was low in the east. Even so, visibility had to be excellent to catch the jettisoned nose fairings as they tumbled away glinting in the sunlight.

But for the northerly firings no suitable pair of camera sites existed some 80 kilometres north of the rangehead. They had to be specially installed. WRE looked at several possible places. Early in 1967 the best technical solution seemed to be two new sites, one at Peephabie Cliff on the left flank and another at Middle Ridge on the right. But both places were hard to get to, and building a site at either might have cost as much as $246 000.[22] The eventual more economical decision was to use the existing V52 Rakimo site to cover the left flank, while on the right a new post was built just outside the opal-mining township of Andamooka. Here access was quite good and there was a convenient PMG microwave communication link nearby and accommodation for the staff in town. A station on this site could track Black Arrow from the time when it had risen about 3 kilometres above the launcher until it vanished over the northern horizon. At a cost of $55 000 the new site was built between June 1969 and March 1970. As described in Chapter 14, a special trailer known as the Rakimobile was built to transport and house the Rakimo, so that it could be moved quickly to the new site. There a fenced compound protected the Rakimobile, a portable generator and a caravan to house the crew and the communication centre. The camera went in as soon as the date of the first northerly firing of Black Arrow was confirmed, a few months later.

While WRE's Optical Group busied themselves with the intricacies of long distance photography, the Telemetry Systems Group was occupied with its own problems. One of the trickiest was how best to receive the transmissions from the third stage of Black Arrow as it performed its vital actions at a distance of nearly 1850 kilometres. Signals from the stage probably could be received at Woomera, but as they would be coming from a point very low on the horizon they would be weak. Good reception was essential, especially in the later firings when it was important to know whether the third stage had gained sufficient speed to enter the desired orbit, or indeed, any orbit at all.

Once again the north-west firing could be handled more easily, since the third stage motor would not be live and hence there would be no exhaust flame to disrupt the signals. First thoughts were to rely on the telemetry station already in place 170 kilometres down-range at Mirikata, but calculations soon showed that this small reduction in transmission distance was not likely to improve the reception much. At the end of 1967 WRE was considering the use of a mobile telemetry station at, say, Carnarvon on the west coast, since this could afterwards be moved to the far north for the later firings.[23] However, a simpler solution for the north-west firing was adopted in the following year. At Central Bore near Mt Eba the huge steerable dish of the SRI radar, installed for the Dazzle program in 1966, was still in place. At a cost of $33 000 (billed to Britain as the Range user after a new financial agreement had come into effect), this was adapted to work as the new and very sensitive telemetry station, M37. By March 1969 it was ready for its final checks, which included special aircraft flights to test its capability of receiving telemetry transmissions from a great distance.

Central Bore was in operation in time for the first firing, and in fact remained in use in a supporting role when the northerly flights began, albeit with less confidence because the flame interference was now present. However, in the R3 trial the third stage data was to be transmitted by the satellite telemetry sender which worked on a different frequency band, and since further modification of Central Bore was uneconomic the station closed. Most of the electronic gear was removed but the great dish, now only a rusty roost of eagles, was still standing in 1988.

This still left the question of a telemetry installation for the northerly firings. As far as RAE was concerned, one of the most important functions of the third stage telemetry was to provide immediate information on the nature of the orbit that had been attained. To do this, a rather detailed computation was necessary which required the telemetered data to be combined with the FPS-16 radar tracking measurements. For this purpose a continuous communication link would have to be set up between the down-range telemetry station and the rangehead. Theoretically the proposed system was a good one, but it was new and untried, and thus it was desirable to have practical proof that it would work correctly before the full scale satellite launching program began in earnest.[24] The ELDO down-range guidance station which was already in operation at Gove was quite capable of tracking Black Arrow and making the desired orbital measurements; thus it was an obvious means of getting independent confirmation that Black Arrow's own system was satisfactory. However, there were certain limitations; to use the ELDO system, Black Arrow would have to be fitted with a special L-band transponder which was too large and heavy to be carried in the third stage along with the satellite. Also, of course, the assistance of ELDO would be required, and it was uncertain that its Gove station would still be in operation at the time when the comparison trial could take place. These factors meant that the combined test could be done only on the first, or perhaps the first two, of the northerly firings of Black Arrow.

While RAE tackled their problems, work continued at WRE on the design and siting of the down-range telemetry station. It was clear that it would have to be placed well to one side of the Black Arrow flight path in order to give a sideways look which would minimise the interference effects of the motor flame. The station could be at Gove as well, but this wasn't essential—it could be anywhere in the north as long as it satisfied the fairly stringent requirements. By February 1968 WRE had evaluated no fewer than ten possible sites, ranging from Cairns and Townsville on the Queensland coast to Tennant Creek in the Northern Territory.[25] The site had to have good communications back to Woomera by Telecom land-lines; it also had to be in a position where the received signals would be strong and not impeded by the motor flame, and where signals emanating from a point low on the horizon would not be blocked by surrounding hills. Gove was quickly ruled out because of its isolation and inadequate communications, and eventually the choice narrowed down to either Townsville or Charters Towers in Queensland. An inspection on the spot revealed that the large RAAF communications centre at Townsville might cause interference, so the choice fell on Charters Towers.

The detailed survey and equipment provisioning for the station began early in 1969. A small delegation including the ubiquitous Ken Smith, who was now with the British research staff at WRE, visited Charters Towers in March to meet the airfield authorities and to conduct radio frequency checks at the site. They were enthusiastically greeted by the Town Council and pressmen at the City Hall, as though few things had so enlivened the quiet pastoral centre since its riotous goldrush days a century before. WRE's activities caught the imagination of the residents, and the local paper published a long and remarkably accurate verbatim account the next day.[26]

With good support from the local branch of the Department of Civil Aviation the station was built on a small airfield just outside the town, where it shared the living facilities of the terminal building. It consisted mainly of the telemetry receiving aerial, a dish 4 metres across, an air-conditioned van for the electronic gear and, some distance away, two masts supporting a precisely aligned aerial for receiving timing signals from Melbourne. Building began in June 1969 and that September a convoy of vehicles carrying the equipment set out from Salisbury on the long trip north. All was ready by October 1969, well in advance of the first northerly firing of Black Arrow.

THE DEVELOPMENT FLIGHT PROGRAM

In 1964, when Black Arrow was given 'limited approval' to proceed, it was hoped to have the development program of five launches completed by January 1968—less than four years away. This was far too optimistic. Money for the project was so tight over the next two years that a realistic flight program—now curtailed to three firings only—was not set until the end of 1966. The first launch was then planned for June 1968, with the other two following within fifteen months.[27]

Unfortunately a series of problems beset the production of Black Arrow in Britain, most of them to do with the Gamma 8 engine. Rolls-Royce, which had absorbed Armstrong-Siddeley, the original joint developer of Gamma, had modified its combustion chambers to reduce their weight. During the fifth test-firing at the Ansty site one of the chambers burst, badly damaging the rest of the engine. The metal bands around the complex assembly of tubes forming the chamber had failed. Strengthening these bands was costly since fifty of the modified chambers had already been constructed—not without great difficulty, because of persistent welding problems.[28] Nor was this the end of the setbacks. The catalyst—a pack of silver- plated gauze discs which decomposed the HTP as it entered the chambers—rapidly became inefficient, and this contributed to a disastrous explosion when the rebuilt engine was tested again early in 1968. The engine was totally destroyed and the test frame inside its blast wall badly damaged in the ensuing fire. Eventually the catalyst problem was solved by increasing the number of discs and silvering some of them more heavily, and by testing more thoroughly the quality of HTP long in store, which had also contributed to the failures. Eight months went by before a perfected engine was ready for delivery. Such was the cost of working right on the edge of the engineering limits while being starved of funds at the same time.

Meanwhile the testing of Black Arrow's elaborate control systems at Highdown had not been trouble-free either. Persistent instabilities took months of work to eradicate and when the second stage was at last tested its Gamma 2 engine was damaged by debris introduced into the fuel from a dirty transfer tank. The date of the launch slipped further and further back—to March and finally to June 1969. This was a full year behind schedule.

As often happened, these delays were not entirely unwelcome at Woomera, where there had been problems in laying on supplies of high pressure nitrogen gas. However the new 5B launcher and gantry were finished well ahead of time and in November 1968 a complete Black Arrow prototype arrived and was erected on the launcher to check that the reconstruction of 5B had been done properly. This prototype, PI, was not a flyable rocket. It was a full scale model, built to test the construction, integrity and flexing of the rocket body, as well as its fit in the launcher. It had few if any innards.

'Jock' McLoughlin, key member of the contractors' team. A De Havilland man and survivor of the 1956 Blue Jay accident, he was involved with Black Knight as well as Black Arrow.

THE BRIEF FLIGHT OF BLACK ARROW R0

The British trial team began to arrive in April 1969. Its OISC (Officer in Scientific Charge) for the first firing was Bill Arklay, a forthright Scotsman from Fife who was notable for his amazing stamina during trials. When off duty he would lead sing-songs in the mess, playing his banjo-mandolin far into the small hours—yet he was invariably one of the first to arrive at the Range in the morning.

As yet Arklay's team had no rocket to fire. Black Arrow R0 was still in transit by sea on board the SS E*tolis*. The vessel reached Port Adelaide on 14 May and some of the team and a bevy of WRE photographers rushed down to the docks to watch the unloading. But there was no reason to hurry. It was dawn the next day before the crate holding the rocket was hoisted from the depths of the hold and loaded on its road transport to Woomera.

By late May a complete team of some fifty men from RAE and the contractor firms was assembled at Woomera, with about as many again of the WRE and permanent Range staff becoming progressively involved as the firing date approached. The schedule allowed twenty-nine working days for the assembly and prelaunch testing, or with breaks, six weeks. There was plenty to do: separate test- firings of the first and second stage engines, the step by step assembly of the complete rocket on Launcher 5B, a series of radio transmission

Bill Arklay (*centre*) with his banjo-mandolin during Christmas celebrations in 1969. The singer at left is Bob Reeds, and Ian Peattie is the organist. (Ken Smith) and interference checks, and finally a rehearsal of the launching sequence to ensure that each part of the operating chain functioned correctly. Many faults and difficulties came to light in the process, but after all this was the first of the Black Arrows and the preparations still adhered closely to the plan. The British technicians had done their remedial work well, and each engine ran smoothly on its first static-firing. At the end of the day's work on 23 June the rocket was declared fit for launching on the following morning—a day earlier than scheduled.

The time slot allowed for the launch was from 8 to 10.30 a.m., so few of the team got much sleep overnight. Many of them worked with the Range staff in loading the HTP, topping up the kerosene fuel tanks, inserting the break-up capsules, arming the explosive circuits, and checking all the emergency stop actions and the timing systems.

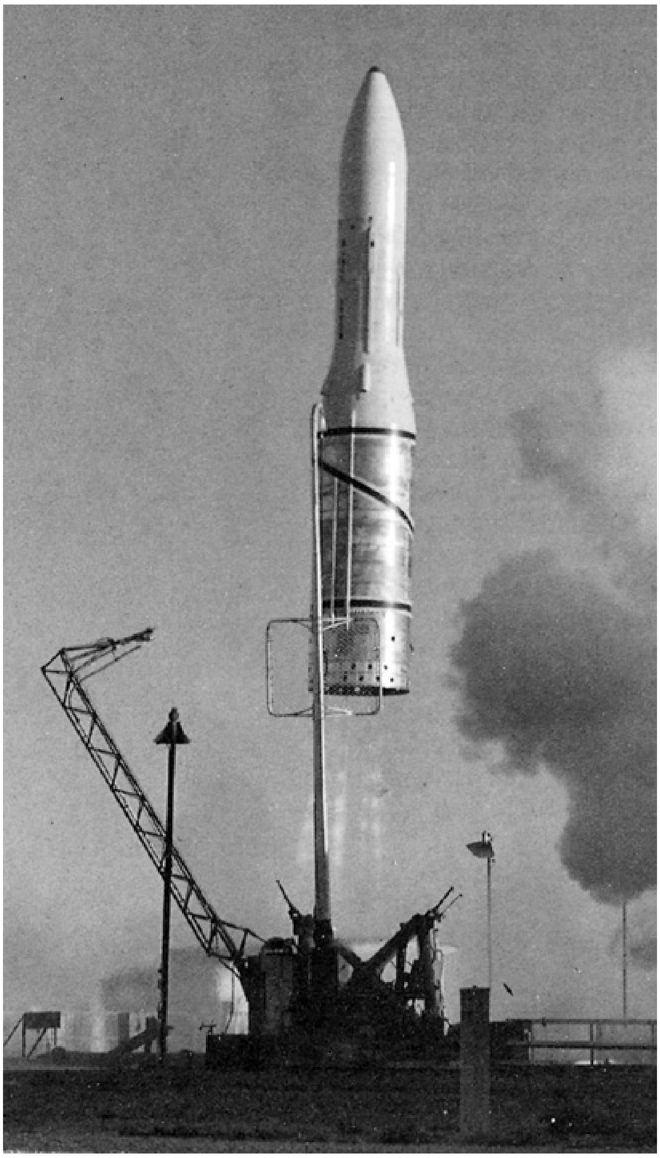
Black Arrow R0 was somewhat simpler than the later vehicles since it did not have a live third stage; nevertheless the brightly lit launch area was the scene of constant activity throughout the small hours. In Test Shop 4 constant checks were made of the velocity of wind in the upper levels of the atmosphere. A high velocity jet stream, for example, could overstress the heading control system with disastrous results. Periodically the Range meteorological office issued measurements of the wind conditions up as high as 15 kilometres in steps of 300 metres. For each separate reading a complicated calculation had to be performed, using a mechanical adding machine of the kind everyone had to use then. In fact, the wind speeds were excessive at 3 a.m. but fortunately by 6.30 a.m. they had moderated.

From 5 a.m., the trial and Range teams were provided with a magnificent breakfast at Koolymilka—a chance to let the nerves relax and for a little last minute conferring. As the staff returned to their posts, dawn was breaking to a beautiful sunrise and clear sky. Conditions appeared perfect and the final countdown began. But at this point, problems arose. The train of operations was held up for two hours while faults were dealt with on a Range safety tracker and the rocket first stage telemetry sender. At 10 a.m., almost at the point of launch, the automatic lift-off sequence was halted when the flight programmer in the second stage failed to start. By the time the trouble was fixed—it was a fault in the ground cabling network—it was too late to proceed and the trial was abandoned for the day.

Of course it was disappointing, but the teams had now had a full dress rehearsal, and on the following night they ran through the whole launch preparation again so smoothly that it was finished two hours early.[29] The sky was clear at dawn, but then it clouded over totally. The countdown was held for a while but the overcast did not clear and the launch was again cancelled. There was some pressure for a third attempt on the next day, particularly to avoid a clash with ELDO's F8 launch which was scheduled for 30 June, but HTP had to be off-loaded, batteries replaced and the attitude reference unit realigned, which, combined with an unfavourable weather forecast, persuaded Arklay that a two day postponement was essential.

On the morning of Saturday 28 June the preparations were again completed in good time. The team was becoming accustomed to night work; already hungry before breakfast was served at Koolymilka, they used the spare time to cook pasties by the electric radiators in Test Shop 4. Dawn came on a clear morning, and the sequence proceeded with only one minor hold-up. At 8.28 a.m., Black Arrow R0 lifted off.

As soon as the ascent began it was obvious something was amiss. The rocket was rolling violently, twisting to and fro as it climbed painfully into the sky like a pencil twiddled slowly between finger and thumb. After a minute or so the awed observers saw the nose fairings and then the payload itself tear away. The engine flamed out, but still the rocket climbed ahead of a dense white trail of smoke. Slowly it started to pitch nose over tail as it rose to 8 kilometres. Then it began to fall. Up came the Flight Safety Officer's voice over the intercom, 'vehicle descending; breakup action will be taken at 9000 feet . . . break-up *now*'. An instant later Black Arrow R0 disintegrated in a cloud of flaming propellant and scattering debris. The observers on the balcony of the Instrumentation Building received a striking reminder that light travels faster than sound. Having watched the explosion they turned away after ten seconds or so . . . to be startled by a deafening thunderclap which rattled the windows and echoed from the surrounding buildings. Most of the remnants fell a few kilometres down-range, but the lighter fragments of tank skin were scattered far and wide by the wind. The payload lay not far from the launcher, flattened and split but still almost complete.



Above: The first Black Arrow, R0, lifts off bravely. *Above right*: Its destruction in flight a few minutes later. *Bottom right*: Remains of R0 payload after impact.

The telemetry records showed that the cause of the failure was probably a loss of swivelling control to a pair of the engine combustion chambers. The diagnosis was later confirmed by a three dimensional computer simulation of the flight at RAE. Exactly where the circuit had failed could not be determined—it may have been a single broken wire—but elaborate measures were taken during later construction and testing to ensure that the fault did not recur.

On 30 June a first group of the trials team started a despondent trip home. The air of gloom intensified when a hoaxer phoned the airport claiming that a bomb had been placed on the charter aircraft. All the baggage and freight had to be taken off and searched before the flight was allowed to begin its long journey. Bill Arklay and the other specialists spent a further two weeks at WRE, examining the trial records and considering the future program.

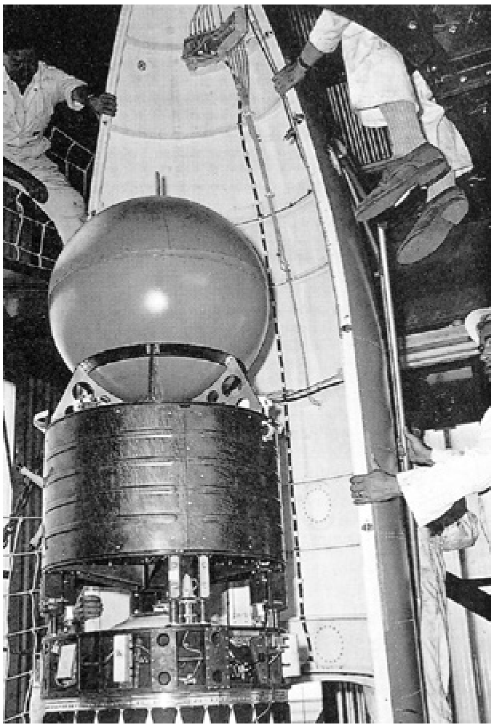
R1 REACHES THE INDIAN OCEAN

The next trial, Black Arrow Rl, had been planned as a three stage northerly firing to carry a simple satellite into orbit, on the assumption that R0 would have proved the basic rocket system. Obviously this had not been achieved, and although various possibilities were considered it was recognised by the administration at Space Headquarters in London that the unsuccessful trial would have to be repeated.[30] By the beginning of August 1969 work had started on rewriting the trial specifications and modifying the nearly completed Rl vehicle to be a replica of R0. The task was undertaken with urgency, and since no new major work was necessary at Woomera, it was decided that the next trial could still take place on its scheduled date in November 1969.

This tight schedule allowed only six weeks for the modifications to be done at Highdown, which included fitting some improved components in the engine control circuits to prevent a repetition of the R0 failure. No sooner was this done than ominous cracks appeared in the steel bottles which pressurised the propellant tanks. As time was running short and the problem was understood, renovations were left to be done at Woomera as part of the launch preparation.[31] By the middle of September the first stage of R1 was on its way by sea and its second stage by air. The latter arrived quickly and when the team began to gather with Bill Arklay again in scientific charge and with Bob Reeds as his deputy, the stage was checked thoroughly over the next three weeks.

By this time the first stage should have arrived at Port Adelaide but in fact was only approaching Fremantle. Arklay realised that a week could be saved by offloading it there and bringing it by rail to Pimba. Reeds hastened to Perth to organise the transfer and by 23 October it was being checked in Test Shop 4. The assembled rocket was in the launcher when fierce Spring storms, strong enough to bring down power lines, delayed matters. Still, by 11 November the first stage engine had been test-fired successfully, although certain worrying intermittent faults showed in the control system. Though they were apparently cured, they returned to dog preparations later.

On 21 November, with only four days of work remaining before the launching, Arklay was called from his dinner table at the mess to take an urgent phone call from Farnborough. In question was the strength of the nose cone fairings, which had broken off during the short violent flight of Black Arrow R0. Project Officer Leslie Parkin called a halt while this was sorted out over a week of hectic communications and modifications. Time was now critically short. Christmas was approaching, and with it the Range stand-down. The Britons, far from their families, began to look anxiously at the scheduling of the charter service. Arklay decided on a further launching attempt on 4 December, and preparations got under way once more. But at this point the mysterious control system failure cropped up again and lingered long enough to be identified as an obscure design fault which could not easily be remedied. This final blow gave no alternative but to postpone the trial for two months until the end of January 1970. The Black Arrow itself was covered with a dust sheet in its 5B gantry, while its most delicate equipment was removed to safe storage in Test Shop 4. After waiting a week—during which time Hermann Thumm's Yaldara winery proved as attractive a venue as in the old Black Knight days—the Britons were all home for Christmas.



Far *left*: The test satellite in position on top of R1. One of the two nose fairings is being fitted.

Left: The first stage of R1 after impact, following a copybook flight.

The team returned to Woomera on 24 January 1970 by the first flight, refreshed after their Christmas holiday. The renewed trial preparations got off to a flying start, as the Australians had already uncovered Black Arrow and checked the launcher installations. At the recommendation of Rolls-Royce, the second stage was moved to gantry 5A and a further engine test-firing carried out—again successfully. With the complete rocket reassembled, the lead-up to the launching began. The control system, its design now perfected, operated without any hitch. But again the weather showed itself to be unkind, initially by extreme heat which made work very arduous and also affected the equipment. Despite the use of extra cooling the temperature in the instrumentation compartment reached 60 degrees Centigrade. Then, as the launch date approached, a thick cloud cover over the Range threatened to become a permanent fixture.

On the three successive nights of 18 to 20 February the familiar ritual of preparation was repeated: the fuelling and the arming of explosives, the tedious calculations of high level winds, the tension relieving breakfast at Koolymilka. On the first morning, dawn revealed impenetrable cloud, while on the second a problem with a safety tracker held up the countdown while the clouds again inexorably gathered. The third morning was clear: all systems were 'go'. At time zero, the engine ignited in a billow of smoke and steam . . . only to be shut down a few seconds later when the equipment centre monitors indicated a fault. There was in fact no failure of the engine, but merely a defect in the recording system. Two more launches, scheduled for 24 and 25 February, were cancelled early in the preparation because of equipment faults. At a fourth attempt two days later the cloud had returned.

At this point Arklay wisely decided that everyone had had enough. He ordered a few days off. Magically, this broke the spell. At the next attempt the preparations went smoothly until dawn when the clouds began to accumulate again. The countdown was hurriedly advanced and at 6.45 a.m. on 4 March 1970 Black Arrow R1 rose smoothly from its launcher and accelerated away to the north-west.

The second stage separation and ignition were recorded by the Rakimo cameras at V51 and V52, although the jettisoning of the nose fairings was obscured by an advancing patch of cloud. The event was recorded by other Range cameras. Both FPS-16 radars tracked the flight: one steadily for almost ten minutes and then by snatches well beyond the third stage separation as Black Arrow started its long curve down into the Indian Ocean.[32] Telemetry reception from the third stage, for which the Central Bore station had been established, was poor: the signals faded intermittently during the important spin-up and separation. Telemetry from the second stage showed that they occurred on cue.

Despite the tribulations of the long delayed launch, the analysis of the trials record showed that R1 had been an almost perfect flight. Air drag had slightly reduced the acceleration of the first stage as it passed through the sound barrier, but the engine's efficiency, greater than predicted, had more or less offset this effect.[33] Black Arrow had earned its laurels, and the congratulations came pouring in. The British Minister of Technology, Wedgwood Benn, referred to the efforts of WRE, which Director Woods modestly discounted by saying that, 'most of the credit must go to the Black Arrow team, but we are glad to have played our part'.[34]

Arklay was now anxious to get clearance for a northerly flight path for R2. George Foreshew, the Principal Safety Officer, predicted that the performance of Black Arrow so far would pass muster and he proved to be right. But formal acquiescence to the new trajectory only came through several months later, when the preparation for the flight of R2 was well advanced.

R2 HEADS NORTH

Black Arrow R2 had all three stages operational for the first time and the trial had a triple purpose: to flight-test the Waxwing motor, to prove that the ground stations could obtain data over the course of the northerly flight path, and to put a small satellite into orbit. The satellite, Orba, was a simple hollow sphere of gold-plated aluminium 76 centimetres in diameter. It contained only a little transmitter sending a continuous signal, using the sphere itself as an aerial. Even so, during its month in space Orba would serve some scientific purpose. The gradual changes in its orbit caused by the tenuous upper atmosphere could then be recorded, enabling the cyclically varying air density in that region to be measured.

By early May 1970 R2 was ready for shipment. The first two stages went by sea, but a dearth of cargo shipping caused an annoying delay of a month before the crates left England. When the SS M*argaret* at last arrived at Port Adelaide on 20 July most of the British team, this time with Ian Peattie in scientific charge, were already there.

In the meantime preparations at Woomera had not been going well. During the previous trial the large underground main, which brought huge quantities of cooling water to Area 5, had given trouble. It dated from the Black Knight days and had already burst four times.[35] Range Engineer Leon Wraczynski advised replacement, but when nothing had happened after three months even the equable Ken Smith was moved to complain about WRE's 'disgraceful procrastination', which finally got results.[36] Installing the nitrogen gas system was still proving tiresome: components failed to arrive, so that in the end a temporary arrangement had to be set up hurriedly for the R2 trial. Finally, the supply of the HTP propellant was an increasing source of anxiety. Manufacturing problems at the Sydney suppliers repeatedly held up deliveries, and only two weeks remained to the scheduled launching date when the last supply tankers arrived at the Range.[37]

Despite these worries, the trials work at the Range proceeded extremely well. The team was larger than on previous occasions as it included members of the Spacecraft Division from RAE and their contractors, who were observing procedures and co-operating in this first orbital launching. (Also for the first time, part of the team lived in the comfortable ELDO mess at Woomera.) Test Shop 4 was the initial scene of activity, where the rocket equipment was being checked, and in the air- conditioned cleanroom the delicate gold surface of the Orba satellite was meticulously cleaned. The 5B launcher was rotated to its new alignment to the north and was made ready to receive the Black Arrow.

The full program of tests at Area 5 occupied the whole of August, following the pre-arranged plan and occasionally getting ahead of it. Each of the two engines operated perfectly when it was test-fired, and at the end of the month R2, surmounted by its golden ball, was erect on the launcher in readiness for the final countdown day. Down-range, the tracking stations at Andamooka, Charters Towers and Gove were equipped, checked and ready.

The launch was scheduled for 1 September between 7.30 and 10 a.m. The HTP loading and final rocket preparations were carried out throughout the small hours and, as the launch time approached, direct telephone and teleprinter links were opened to provide instant information from the rangehead to Space Headquarters in London. After the last go-checks with all the Range stations, the final two- minute sequence began precisely on time. Just thirty-five seconds before ignition Gove station called 'stop'. It had a computer fault. The tension rose unbearably at the rangehead while far to the north the staff worked feverishly to cure the problem. But the time slot expired with it unresolved and the launch was abandoned for the day.

Gove was ready again by evening, and the night's preparations were put in train once more. At dawn the whole complex organisation was ready, but now the weather looked unkind. Over the next two hours the wind abated and the sky cleared, and at last Peattie gave the go ahead. Black Arrow R2 lifted off at 10.04 a.m. on 2 September 1970.

The launch was perfect. As the rocket rose and headed into the northern sky the observers in the Instrumentation Building supplied a commentary to a small midnight audience gathered round the phone at Castlewood House in New Oxford Street. The new camera post at Andamooka captured the smooth separation of the first stage, and then one of the nose cone fairings as it whirled away. The other half was not apparent—perhaps it had stuck. The FPS-16 radars tracked the flight well into the coasting phase, although towards the end there were some unexpected fluctuations of the radar signal which suggested that the rocket attitude control might be unstable. The telemetry station at Charters Towers, in use for the first time, proved highly successful. It picked up the third stage telemetry signals very early on the approach, continued to receive them for about six minutes as Black Arrow passed by, and retransmitted the data live to Woomera over the ground communication lines. The Gove station was in radio contact with the third stage transponder for a similar period and produced its independent record of the trajectory.[38]

It was the excellent telemetry and tracking records which showed that unfortunately something was wrong during the second stage part of the flight. For some reason the engine closed down about half a minute short of its two-minute burning time. All the subsequent events of third stage propulsion, spin-up and separation had been perfect, but the loss of thrust meant that the final speed of the third stage was insufficient to take the satellite into orbit. Instead, it descended in a long curving path to the sea in the Gulf of Carpentaria. The fragments of the second stage fell somewhere in northern Australia, and have never been reported. However, early in 1971 the second nose fairing was found near Avon Downs in the Northern Territory. Somehow it had stayed locked in position through the coasting stage and had been thrown clear when the third stage spin-up rockets had ignited.

The customary celebrations that evening were rather muted as everyone was disappointed by the loss of Orba. Yet many objectives of the trial had been achieved. The third stage had performed flawlessly and so had the reoriented launcher and the Range instrumentation network. In fact Peattie later recommended that if the failure in the second stage could be located and cured, the R3 trial with its operational satellite should go ahead as planned.[39]

This proved to be the case. In the following month a complete analysis of the telemetry records showed that the second stage engine was blameless. A small leak in a nitrogen gas pipe had caused loss of pressure in the HTP tank, so that the engine had been starved of its propellant. The nose fairing had merely been jammed by a tight electrical connector. And the loss of attitude control, first indicated by the radar-tracking data, had been due to the temporary inaction of a magnetic locking valve, probably caused by excessive vibration as the second stage engine cut out.[40] Improvements to cure all these problems were installed and tested at Highdown, and events moved steadily towards the launching of the Prospero satellite on R3.

R3: PROSPERO IN ORBIT

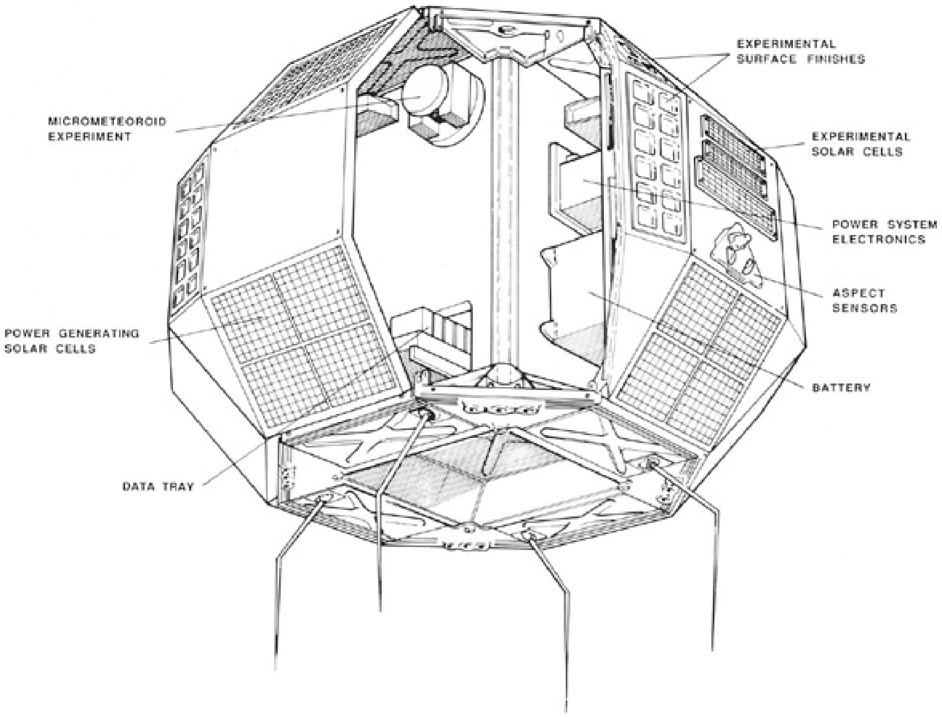
At the time of the R2 trial, the construction and testing of the first 'utilisation' satellite, Prospero (X3), was very well advanced, and work had in fact already begun on two of its planned successors. The Spacecraft Division at RAE had sent two missions to WRE in 1969-70 to detail the special facilities required by X3.[41] More than thirty additional people from RAE and the contractors would join the trials team to prepare the satellite. In Test Shop 4 and its cleanroom and adjacent control area would be installed a huge array of computerised monitoring equipment and a large rotating balance machine on which the satellite would be mounted to check and ensure perfect alignment of its spin axis. The immaculate cleanliness of the satellite called for new safeguards during its final placement in the rocket. It was conveyed from its haven in Test Shop 4 over dusty roads to the cleanroom at the top of Gantry 5B in a special sealed and air-conditioned trailer.

The Test Shop would be the nerve centre of satellite operations, with links by radio and land-line to the launch area, rangehead and the down-range station at Charters Towers. From the time of lift-off until the first few orbits had been completed, Woomera would be part of a global network of tracking stations via direct phone and teleprinter links to London and Farnborough from the Network Control Centre—the grand name for a couple of offices in the Instrumentation Building, temporarily wrested away from their usual occupants.

The basic design of satellite X3 was established as early as 1967. In shape Prospero was an angular pumpkin just over a metre wide and 70 centimetres high weighing 72 kilograms: about the same as WRESAT although internally it was far more complex. The design was compact, with no projections except for the four radio aerials on its base. The panels holding the 3000 solar cells which supplied its electricity were attached to the surface and were not on extended paddles as is the more usual practice.

Prospero was built in Bristol by the British Aircraft Corporation, which had previously built the Ariel series launched by NASA. Marconi supplied the internal electronics and joined with RAE in integrating and testing the completed device. In fact two complete Prosperos were built: one designated the 'F' (Flight) and the other the 'A' (Assembly) model. The latter was for type testing and assembly checks, and to act as an emergency spare.

Prospero carried four experiments.[42] The first was a test of the efficiency of various cladding or skin materials in controlling temperature—a vital function when a spacecraft needs to regulate its interior heat by absorbing or reflecting sunlight to just the right degree. Prospero had ten different panels of test surfaces, each with a device attached to measure fluctuations in its temperature over time. The second experiment was a test of three new types of solar cell, also mounted on panels with their measuring instruments. (They were, of course, distinct from the satellite's own power cells.) Also under test were various



The compact pumpkin shape of Prospero, the UK satellite launched by Black Arrow in 1971 and still in orbit.

cover materials—the thin transparent slips of prepared silica or glass which protected the elements of the solar cell from damaging radiation. The third experiment tested a complex electronic device, made at RAE using a ‘hybrid’ technique, half-way along the road from individually wired components to integrated circuits, which were then in their infancy. The purpose was to gauge its performance against that of a similar on-board unit of standard construction. Fourthly and lastly Birmingham University had supplied a micro-meteoroid detector consisting of a molybdenum target and associated amplifying and counting electronics. It could record the impact of particles of space dust less than a ten-thousandth of a millimetre across. Apart from its basic scientific interest the acquired information would be relevant to the other experiments mounted on the surface, as space dust eventually has an abrasive effect akin to sand blasting.

The outpourings of data from these experiments were of course transmitted to the ground stations over the many months of the satellite’s working life. In practice most of Prospero’s contents were devoted to these tasks: circuitry to organise and encode the stream of data, telemetry transmitters, receivers and actuators to receive and to effect commands from the ground, and finally the power supplies to operate everything. All of this was the ‘common equipment’ which served all the experiments and could be (and was) used on other spacecraft with very different objectives. In another sense, the equipment was most uncommon at the time; it had been produced specifically for X3 and embodied many new principles of design and modular construction which were undergoing their first flight proving, along with the practical experiments. Since the entire operation of the spacecraft depended on it, the common equipment had to be extremely reliable. A degree of redundancy was built in by using standby units which rectified some localised failures. Many of these were switched into circuit automatically by a suite of computer programs which recognised an abnormal occurrence and knew what remedial action to take. Only in an unforeseen situation did the controller need to be involved. This philosophy of ‘management by exception’ was the brainchild of Don Hardy at RAE.[43]

Prospero had two identical telemetry transmitters. Either of them, when turned on by a ground command, could send data at the rate of 2048 bits per second. As well as being sent to the ground in real time, the data gathered during one complete orbit were recorded on board. This was essential as no ground station would be in range over certain parts of the orbit. Once Prospero moved into radio contact again, usually with the station at Lasham near Farnborough, the recorder would replay its entire data store from the preceding orbit in a four-minute burst. This recorder was a very elegant piece of engineering. It used a single loop of tape and was sealed in a container filled with air at a specified humidity. The tape would not traverse the magnetic heads properly in the vacuum of space.

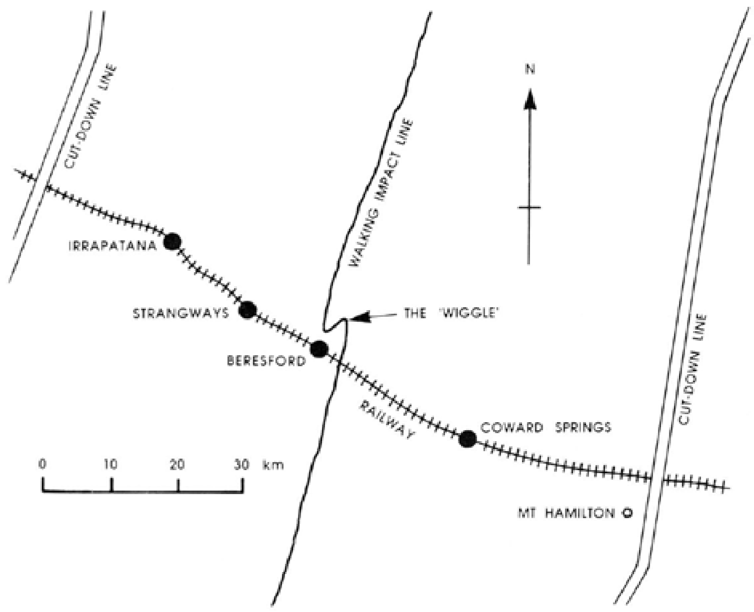
The command reception system in X3 also employed two separate receivers, sharing the same aerials as the telemetry transmitters but working on a slightly different radio frequency. However, the command receivers could not be switched off; they were always in simultaneous operation, and the satellite circuits selected for use whichever one gave the better signal. The command decoders were capable of interpreting forty different commands for action, including numerous on-off switching operations and functional system interchanges within the satellite.[44]

While the spacecraft was circling in orbit, its attitude was held stable by the spinning motion which had been imposed before it separated from the third stage. Two of the on-board experiments required a more detailed knowledge of the spin conditions, such as the rotation rate, the angular position at any instant, and the angle of the spin axis in relation to the sun and earth. Two pairs of sensing devices were fitted to the satellite body to make these measurements, which they did by recording the direction of the sun and of the earth's horizon as they appeared momentarily through viewing slits in the course of each rotation.[45]

With the completion of the improvements which stemmed from the R2 and earlier development trials, Black Arrow was by now accepted as a fully proven satellite launching vehicle. For the R3 flight, its prime objective was stated simply as 'the injection into orbit of the X3 satellite'. The Highdown tests of the assembled rocket began somewhat inauspiciously in April 1971, many weeks behind schedule largely due to a long strike at Rolls-Royce. However, as they got under way all seemed set fair for a launch by the middle of September. Most of the test program had become routine, but this time there was trouble. The first stage test-firing appeared normal, but later inspection showed two of the combustion chambers were badly damaged. It had to be rebuilt by Rolls-Royce after the failure had been traced to blockages in the chamber HTP tubes, caused by debris from a disintegrating catalyst pack.

Fortunately, the remainder of the Highdown work was completed over the next six weeks with few difficulties. The A-model satellite was brought to the Highdown gantry to be checked for the first time in position on the upper stages. The radio transmission tests then showed some interference effects on the WREBUS receivers. This was assumed—falsely, as it turned out—to be due to internal reflections within the enclosed space of the gantry, which could not be rolled back. The second stage engine performed perfectly at its firing test. By mid-July, the first stage (still minus its engine) was en route to Australia by sea and the second stage followed shortly afterwards by air.

While work was in progress at Highdown, RAE had to deal with a longstanding problem: the 'Beresford wiggle'. On both the previous flights the FPS-16 radars which tracked Black Arrow had displayed an odd effect. During the R2 flight, there had been a sudden and inexplicable displacement or kink in the walking impact line as it passed by Beresford station (hence the name). Everyone remembered uneasily that as long ago as May 1966 a similar violent effect had occurred during the flight of ELDO's F4. That had led to



The so-called 'Beresford wiggle', a perplexing kink in the plot of the predicted impact point near the Beresford railway siding. The aerial was changed in an attempt to overcome it.

the unnecessary command destruction of the vehicle—a disconcerting thought all round as the R3 launch date approached! WRE thought the cause lay in the rocket aerial's becoming misaligned with the radar at certain points in the flight.[46] John Saywell, trial group leader for radio and navigation, spent weeks on the analysis, at one stage turning his Salisbury office into a spider's web of taut strings as he set up a three dimensional model of the emission patterns. The problem was certainly an elusive one of aerial design and solid geometry, and RAE wasn't happy with any of the proffered explanations. Eventually the engineers decided on a change of aerial type—a pragmatic solution which had worked with Europa.

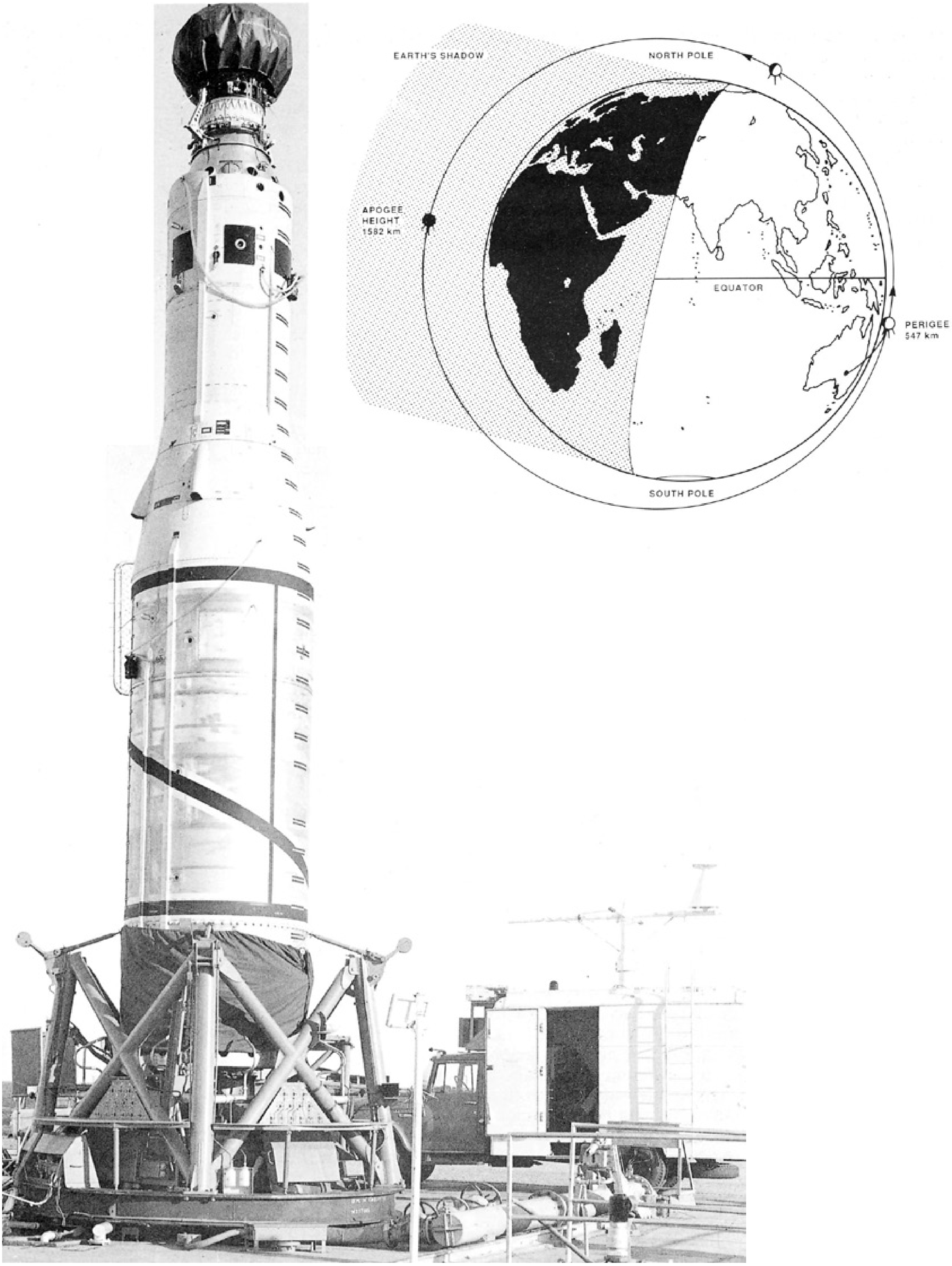
At Woomera the ground preparations for R3 started in the New Year of 1971. At the launch area, the gantry cleanroom was completed and its air-conditioning system installed. The WRE nitrogen gas system was brought nearer to its final design.

One source of concern was again laying on sufficient supplies of HTP, for the stock on hand was losing concentration at an alarming rate. When the same problem had arisen before the R2 trial and things were looking desperate, the Ministry of Defence had helped by sending out two 4500-litre tanks of HTP. This took so long to load and ship that it didn't arrive at Port Adelaide until just before Christmas 1970 as deck cargo on the small vessel SS A*laric*, accompanied by two RAF NCOs whose task throughout the voyage had been to keep the tanks cool and the contents safe by spraying them regularly with seawater. When the tanks had been off-loaded for road transport to Woomera, the WRE drivers were given spades and precise instructions. If the temperature of the cargo started to rise they were to dig a trench quickly and drain the HTP into it, diluting the unstable fluid with water from an extra tank. Fortunately their devotion to duty was never put to this test, but later when the HTP was analysed at the Range it turned out to be useless because of chloride contamination from the seawater.[47] The arrival of fresh supplies from Laportes, the Sydney manufacturers, and some judicious blending with existing stocks solved the problem. The X3 equipment came out in a huge RAF Belfast aircraft which arrived at Woomera airport on 8 July. An advance party of the satellite trials team was there to meet it and no fewer than fifty-one crates of test equipment together with the two satellites were unloaded and taken to Test Shop 4. Within a few weeks everything was installed and a data transmission test carried out between Woomera and the Charters Towers station.

It was just at this point, with everything running forward smoothly for once, that the staggering news broke. On 29 July 1971 the Minister for Aerospace, Frederick Corfield, announced in the House of Commons that Black Arrow was cancelled. R3/ X3 was to be the last launch. Some of the reasoning behind the decision to cancel is given in a postscript to this chapter, but at Woomera the trial teams were stunned and bitterly disappointed. Though everyone knew that the British space program was under review by a parliamentary committee, they could not but feel that the timing of the announcement was appalling. However there was still work to be done, and as the initial shock subsided they recalled that the history of the joint project was littered with such abandonments. They shrugged, and returned to their preparations.

By mid-August all stages of R3 were at Woomera and the full team assembled under Bill Arklay again for this closing firing. Arklay's first action was to assemble the team and to speak of the cancellation. He combined sympathy with encouragement in a spirited speech; he deplored the situation that for some of them the reward for either success or failure would be the loss of their jobs; yet he was confident that the outcome would be success, feeling as he did the general determination to demonstrate the true capability of Black Arrow.[48] So it proved, and as the familiar tempo of the trial built up, the future was left to take care of itself. Early in September the second stage was separately test-fired and then the complete rocket was assembled on the 5B launcher. The full satellite team and some rocket specialists had now joined the trial staff, and among the full complement of nearly one hundred personnel ten different companies and establishments were represented. On 1 October the A-model satellite was fitted to the nose.

The most important remaining tests were for mutual interference between the many radio systems. This was a lengthy and tiresome procedure. It had to be done with the nose fairings removed, as they would be in the later part of the flight, and then with them in place, and in both cases Black Arrow had to stand free of its gantry. A heavy gust of wind could blow the rocket over, and several times the gantry had to be driven back very smartly. The test with the fairings in position revealed a serious problem. The transmitter in the satellite so interfered with the reception of the WREBUS signal (which, we recall, had to be received quite continuously) that the auto-destruct system would trigger. The cause of the trouble was



The WRE radio interference van (*right*) alongside R3 during the mutual interference tests.

Inset: Prospero's initial orbit, and the succession of sunlight and shadow on each.

extremely elusive; many different combinations of transmitters, receivers and external sources had to be methodically investigated. WRE came to assist with their radio interference van (RIVAN), which had special equipment to analyse problems of this nature. The breakthrough came on 13 October when it was first established that the satellite transmitters emitted a spurious signal at a certain position of the small adjacent transfer aerials, which passed the telemetry transmissions through the metal fairing to the main aerials outside. The cure was simply to adjust the shape and position of the transfer aerials.[49]

Don Hardy: a pragmatic but popular decision.

This investigation had cost a week's postponement. Twelve days of preparations remained: fitting the Waxwing motor and other explosives, swapping the A-model satellite for the F-model, and repeating all the laborious freestanding interference tests. All was well, but once again the high winds hindered the work. Don Hardy of RAE describes the tense situation as the tests were done with only a few days to go:[50]

> The test involved rolling back the gantry and operating Prospero while WRE measured the sensitivity of the WREBUS receivers. The difficulty arose in finding a calm period to do the test—the wind speed limit for the satellite was about 30 feet per second, I think. It was decided to do the test on the Saturday before launch immediately after dawn, and Bill Arklay and Bernie Jacobs duly set off to supervise. The calm period did not happen and I took over from them after lunch. We spent a couple of hours watching the anemometer needle fluctuating around the limit, and the team were getting more and more frustrated. (Sunday was the last day in which we could do the test without causing a major hold-up.) It occurred to me that my body had about the same projected area as Prospero, so I stood on the roof of the blockhouse and made a subjective assessment of the effect of the wind while someone read the speed to me over the intercom. I then decided to up the limit by 5 feet per second and instructed the team to roll back the gantry. Immediately after this the wind rose another five feet per second—I took a deep breath and said 'carry on'. The test was done in record time and I don't remember being allowed to buy a drink that evening.

The launch was scheduled for 1.30 p.m. on 28 October. The experiments required a succession of light and shade on each orbit, and, as the diagram shows, a launch at about noon into a polar orbit ensures this. Consequently, unlike the previous trials, the final hours of work did not need to be completed until after dawn. By 11.30 a.m. the launching control and tracking stations were ready. At the Instrumentation Building, a group of distinguished observers had gathered, including the Australian Minister for Supply, R. V. Garland. As the launch time approached, telephone and teleprinter links were opened and Don Hardy and Ken Smith supplied Farnborough and London with a running commentary. Hardy's role as Network Controller was a vital one for satellite operations. His links to Data Central at RAE branched out over teleprinter lines to the European Space Operations Centre at Darmstadt and to tracking stations at Fairbanks (Alaska), Redu (Belgium), Spitzbergen and the Falkland Islands.[51] The weather at Woomera was almost ideal, with only a few patches of thin cloud marring the blue. One such patch was passing over the flight path just before the nominal launch time, and the countdown sequence was halted for a few minutes to allow it to clear. At 1.39 p.m. on 28 October 1971, Black Arrow R3 lifted off.

The ascent was perfect. Andamooka photographed the first stage separation and other cameras the jettisoning of both nose fairings. The FPS-16 radars tracked somewhat variably (evidently the new aerial had not been a panacea), but one radar still maintained contact throughout second stage coasting and separation. The star performers were the telemetry systems, which continued to furnish data out to an incredible distance: Mirikata was still in touch with the second stage thirteen minutes after launch when it was 3000 kilometres away. The Charters Towers station received the satellite transmission as it approached four minutes after launch and continued to do so for a further eleven minutes.[52] These data, relayed instantly back to Test Shop 4, were the first indication that the satellite Prospero was in orbit. Some 40 minutes after launch, the tracking station at Fairbanks reported good signals as Prospero passed over the Arctic heading south in its first orbit. With this news the jubilation at the Range began.

The orbit of Prospero was almost exactly according to plan. It was not circular but elliptical, with an apogee (highest point) of 1582 kilometres and a perigee (lowest point) of 547 kilometres. This was at most only 12 kilometres from the predicted height, owing to a slightly excessive thrust from the third stage. The path of the orbit, intended to cross the equator at an angle of 82.1 degrees, was correct within a fraction of a degree.

Only two unexpected incidents occurred as Prospero started its life in orbit. While it was still close to the separated third stage the two apparently collided, damaging or breaking off one of the satellite's four aerials. The accident slightly altered the pattern of radio emission, but without any practical consequences. The tape recorder ran irregularly for the first few orbits, but it soon corrected itself.

With Prospero safely aloft Britain became the sixth nation to put a satellite into orbit with its own launcher. Woomera Post Office was kept busy that afternoon, stamping the mass of philatelic first day covers that had been confidently prepared for the occasion. The official celebrations began in the evening with a boisterous party in the ELDO mess which continued long into the night. Next day on a special early flight to Adelaide the bewildered hostesses were persuaded to take their leisure while the still emotional team served the refreshments. On the morning after a final garden party most of the Britons started their homeward trip, only too aware that this was more than the end of a single project. Arklay with a few specialists remained at WRE for two weeks to deal with the accumulating trial data and to take part in the post-trial assessment meeting. Official congratulations were quick to arrive. Ian Gilmour, the British Minister of Defence, wrote in tones delicately implying that this was indeed the end of an era:

> I think this is a good example of Anglo-Australian co-operation, and it is particularly pleasing because it has brought the Black Arrow vehicle program to a successful conclusion. I am sure we can look forward over the coming years to many more examples of co-operation in other fields.[53]

Responding to these congratulations, Director Don Woods wrote with a mixture of optimism and resignation that 'we were delighted with the successful launching of Black Arrow. It was a fitting finish, at least for the time being, to satellite launchings from Woomera.'[54]

THE LAST DUTY: DISPOSALS

Black Knight and Black Arrow had between them lasted for fifteen years, and the two projects had accumulated a vast quantity of stores at Salisbury and Woomera. With the close of Black Arrow, the formidable task began of establishing the ownership of the materials and equipment and arranging for their disposal. The year 1972 was drawing to a close before the final movements and accounting were completed.

The satellite check-out equipment in Test Shop 4 was quickly removed since it had other immediate applications; it departed as it came in an RAF aircraft. Most of the vehicle test equipment and consumable materials, numbering many thousands of items in 70 detailed lists, was transferred to other government departments of both countries, while the remainder was scrapped on site or sold at public auctions in Adelaide. From the station at Andamooka, and from the one at Charters Towers, which had had an operational life of just 21 minutes and had cost $170 000, all the reusable gear was removed and the sites with their fixed constructions and hard- standings handed back to the owners or the lessee.

The fixed installations at Area 5 were more difficult to deal with. The launcher stands and steel efflux ducts were hauled from the ground and added to a growing pile of metal junk as the site was cleared. Eventually only the structures of the two gantries remained erect. Jack Redpath, the Westlands manager who had organised their construction from the start, argued for their retention on the grounds that they had almost no scrap value and if left they might attract space projects to Woomera in the future.[55] But Space Headquarters was determined on a clean sweep, and the gantries were advertised on a 'dismantle and remove' basis. Only one contractor liked the look of the job, and his modest offer of $568 was accepted. Even he had second thoughts when he found how much it cost to hire cranes at Woomera. He was minded to withdraw and forfeit his offered price, but finally he solved his problem by cutting through the base supports and dragging the gantries over with a steel rope attached to his tractor.[56]

By October 1972 only the concrete equipment centre remained standing. The launching sites had been levelled to the ground and the huge pile of scrap material carted away. The deserted site was now eerily silent in that special way of places that have once seen great bustle and high emotions. Making his last report to London on the close-down, Smith was moved to quote some sonorous lines from *The Rubaiyat*:

> . . . the lion and the lizard keep
> The courts where Iamshyd gloried and drank deep:
> And Bahram, that great hunter—the wild ass
> Stamps o'er his head, and he lies fast asleep.

By 1976, five years after its launching, Prospero had travelled over a billion kilometres in orbit and was still functioning remarkably well.[57] Even a year's operational life would have pleased the team at Lasham, so the flow of data for another four years was an excellent bonus. Only the tape recorder had ceased to operate. Its delicate mechanism was expected to last six months at the most, but nineteen months elapsed before it finally stopped running. The experiments had all produced good results, particularly the new 'doped glass' protective slips for solar cells which by then were in standard production by Pilkingtons, the glass manufacturers.[58]

On the tenth anniversary of its launch Prospero's electronics were still working correctly and responding to commands, although the telemetry transmitters were normally kept switched off to avoid radio interference with other satellites. Each year Prospero is commanded 'on' briefly for a test. By 1984 the batteries had failed, but it was still operating when in sunlight. Over the years its rate of spin has slowly declined under the braking effect of the earth's magnetic field from its original 175 revolutions each minute to a mere three. This is not fast enough to maintain a stable attitude. Nevertheless, Prospero remains in orbit and in the natural course of events more than a century will pass before it performs its flaming finale in the earth's atmosphere.

POSTSCRIPT: A NOTE ON THE CANCELLATION

The reasons for the dramatic cancellation of Black Arrow belong to the wider story of British enterprise in space and hence are outside the ambit of this history. However, for the sake of completeness a few salient points may be mentioned.

In February 1971 a Select Committee of the House of Commons began to take evidence for its inquiry into all of Britain's space activities including its cooperative efforts with other countries. What to do about Black Arrow was only a small part of the Committee's deliberations, but it did hear many diverse and often conflicting opinions on this particular subject from those who appeared before it. There was general assent that the delays in the program, the infrequent launches and the grudging dispensation of funds meant Black Arrow had had its day. In its present form it could never lift communications satellites into geosynchronous orbits, even with the great shrinkage in electronic componentry which, it was correctly predicted, lay just ahead. Where the testimony heard by the Committee differed was over the same question which had animated discussion back in 1968 when Britain decided to withdraw from the ELDO launcher program. Was it wise for a country to surrender its launcher capabilities altogether so as to become totally reliant on American goodwill? Research satellites were one thing, but military satellites, or commercial satellites offering services competitive with American ones, might be a different story. In the end, however, the man who had the decisive word—the Minister for Aerospace, Frederick Corfield—came to the conclusion that these dangers were exaggerated, and he decided to accept the American assurances. The savings were, after all, considerable. Each relatively small satellite cost about £2 million to launch using a Black Arrow. Using an American launcher would save about £750 000 each time, and the money could well be spent on developing new applications satellites. This was the equation that gave Black Arrow its quietus.

When the Select Committee reported on 27 October 1971 some months after the cancellation (and coincidentally the day before Prospero was launched into orbit), it spoke of the 'parsimonious and half-hearted approach to the [Black Arrow] project which had proved fatal to its success', and went on:

> The technical concept was sound when the programme was begun, but largely owing to its very modest extent and long drawn-out timescale its success was being imperilled. A decision in the early stages of the project to pursue it more realistically and vigorously by increasing the rate of firings might well have achieved successful launchings and eventually a commercial return on its use . . . there seems little reason to criticise the Government's

decision, but it would be wrong to view it as inevitable from the beginning. As so often in the development of new technology, economy in expenditure has resulted in too little being done to achieve success and the money, time and effort that has been expended has been spent to little purpose. It seems to us to be a classic case of 'penny wise, pound foolish'.

The present author can offer no better epitaph on Black Arrow than this.

Notes and Sources

1. The Shakespearian names given to Britain's first satellites was a pleasantly imaginative touch, but it turned into something of a comedy of errors. Ariel, the first to be launched by the US in May 1962, was named in allusion to the sprite who boasted of putting 'a girdle round the earth in forty minutes'. When it came to naming later satellites in the series, Don Hardy of Space Department RAE pointed out that the sprite was not Ariel in *The Tempest*, but Puck in *A Midsummer's Night's Dream*. This name was vetoed for fear of embarrassing the Minister with a slip of the tongue in the House, so Hardy suggested they stick to *The Tempest* and its magical atmosphere, offering the name Prospero. When in 1974 the X4 satellite was to be launched on a Scout rocket it was named Miranda after Prospero's daughter.
2. G. K. C. Pardoe, 'General review of a British space flight programme based on Blue Streak', Unpublished paper delivered at the Commonwealth Spaceflight Symposium, London on 28 August 1959. The Symposium had no governmental backing: it was arranged by the British Interplanetary Society. WRE's Horrie Higgs attended and gave a paper on the facilities at Woomera.
3. The RAE design is shown in Drawing SSK 450. In fact quite a number of Blue Streak/ Black Knight configurations were proposed. Folder SAS 9/31/1 part 1.
4. Minutes of CUKAC Meeting 48 of 8 June 1960.
5. The survey, according to a report dated November 1960, covered possible impact zones in north-west Queensland, the Northern Territory and around the Gulf of Carpentaria. Folder SAS 9/31/1.
6. Letter dated 8 November 1960 from H. A. Wills, Deputy Controller Trials and Instrumentation to H. Higgs, Australian representative in GWA5, London. Folder SAS 9/31/1.
7. Space Department RAE, 'Draft project for a small satellite launcher' dated 23 December 1963. File A5877/2/1.
8. The Controller Guided Weapons and Electronics, Ministry of Aviation, at IPPAC Meeting 6, September 1964.
9. Westland Aircraft Ltd, Saunders-Roe Division: Drawing SR/G2/ SK 1082. File A5877/ 2/1 part 1 folio 1A.
10. Minutes of IPPAC Meeting 6 of September 1964.
11. Letters dated 23 January and 2 February 1967 from WRE Director to Chief Scientist H. A. Wills. File SA5877/2/1.
12. Letters dated 1 March 1968 from Prime Minister John Gorton to Premier Don Dunstan; and dated 2 May 1968 from Premier Steele Hall to Prime Minister Gorton. File A5877/2/1.
13. Report dated May 1965 of the mission visit to WRE in connection with Black Arrow, 15-26 March 1965. File SA5408/34/1.
14. Space Department RAE, The Black Arrow satellite launching vehicle'. RAE Technical Report 69068 (April 1969).
15. A siskin is a small cage-bird. Most of the solid fuel motors developed at Westcott were named after birds: Waxwing, Raven, Stonechat, Cuckoo, etc.
16. Three sets of gimbals, each in a different plane, were enough to keep the central platform stationary. However, certain complicated movements of the vehicle could cause a condition of 'gimbal lock', so the additional gimbal gave assistance in one axis and made the device 'fully aerobatic'. RAE Technical Report 69068.
17. The dispersion of fragments was discussed in detail during the mission visit to WRE in March 1965, at meeting 13. File SA5408/34/1.
18. Black Arrow Planning Specification WRE 1033 Part I (December 1967) gives full details of the filtration and air-conditioning performance for the cleanroom. File F5824/4/2.

19. [Project Black Arrow:] Instrumentation Specification WRE 1033 Part II. Draft issue 1 (June 1967). File C5874/17/1.
20. Originally the prospective Black Arrow firings were labelled Bl, B2, etc. In 1968 under the new nomenclature the first vehicle became R0 with its payload X0, the second Rl/Xl and so on. The Spacecraft Mission to WRE in March 1970 produced initial plans for two further satellites, X4 and X5.
21. Report on the mission visit to WRE of 23 May-3 June 1966 dated July 1966. File SA5408/34/1.
22. Memo dated 17 April 1967 from Dr F. W. Wood, Deputy Director/Trials to Principal Officer, Project Assessment Group. File SA5877/2/1.
23. Project Black Arrow: Instrumentation Specification WRE 1033 Part II. Draft issue 1 (June 1967). File C5874/17/1.
24. Minutes of WRE/BDRSS meeting on down-range telemetry and tracking facilities dated 12 September 1967. File C5874/6/7 (held in file 5911/2/2).
25. Letter dated 7 February 1968 from C. Lightowler, TMS Group WRE to Principal Officer PA Group. File P5515/12/6.
26. Report in *The Northern Miner*, 12 March 1969.
27. Appended paper P(67) 1 dated 17 January 1967 to minutes of JPPAC meeting 11. File A5877/2/1, folio 27A.
28. Reports to the Black Arrow UK Technical Panel Meetings 16 and 20 of 21 June 1967 and 22 February 1968. File F5824/1/2, part 1 folio 22, part 2 folio 8P.
29. Details of the delays to the flight of R0 drawn from the OISC Report and Range Operations Report in minutes of WRE post-trial meeting of 8 July 1969 on vehicle R0. File F5824/12/1,
30. Letter dated 1 August 1969 from K. Smith, BDRSS to Director WRE. File A5877/2/1.
31. Minutes of WRE post-trial meeting of 13 March 1970 on vehicle R1. File F5824/12/1.
32. R1 post-trial meeting: OISC report. File F5824/12/1.
33. Minutes of Black Arrow UK Technical Panel Meeting 33 of 22 April 1970. File F5824/ 1/2, part 5 folio 4.
34. Telex messages dated 4-11 March 1970 between the British Minister of Technology and the Director WRE. File A5877/2/1, part 2 folios 34-7.
35. Memo dated 25 March 1970 from L. Wraczynski, PO/Engineering Woomera to PO/ Planning and Data Analysis. File F5824/1/2.
36. Minutes dated 26 June 1970 of Black Arrow Planning Committee meeting 25. File F5824/1/2, part 5 folio 12.
37. Minutes dated 14 August 1970 of Black Arrow Planning Committee meeting 28. File F5824/1/2, part 5 folio 30.
38. Minutes of WRE post-trial meeting of 10 September 1970 on vehicle R2. File F5824/ 12/1.
39. OISC report in R2 post-trial meeting. File F5824/12/1.
40. Minutes of the Black Arrow UK Technical Panel Meeting 38 of 24 February 1971. File F5824/1/2, part 6 folio 27P.
41. Report dated 7 March 1969 on X3 Spacecraft Mission to WRE of 10-21 February 1969. File F5824/19/2.
42. H. J. H. Sketch, 'The Black Arrow X3 spacecraft'. RAE Technical Report 69203, September 1969.
43. D. D. Hardy, 'Satellite operations and control: proliferate or automate?' RAE Technical Memorandum Space 226, October 1975.
44. V. W. Adams, 'Orbital operations handbook for the X3 satellite'. RAE Technical Report 71172, August 1971.
45. Sketch.
46. V. j. Bosher, 'Impact prediction from DIP for Black Arrow', with appendix 'Investigation of the Beresford Wiggle' dated 15 December 1970. File T5745/2/5.
47. Minutes of Black Arrow WRE Planning Committee Meeting 34 of 28 May 1971. File F5824/1/2, part 6 folio 29.

48. Details of Arklay's speech taken from the private diary of Ken Smith.
49. Unpublished MOD data. The reader may wonder why the interference with WREBUS could not have been cured simply by turning on the satellite transmitters after the WREBUS equipment had been jettisoned. There were several good reasons why the satellite transmitters should operate from launch. It will be recalled that they had to be switched on by radio command from the ground; and if this had been delayed until the later stages of the flight R3 would have been far out of range of the low- power test transmitters in Test Shop 4. Charters Towers could not do it, as it had no command facilities, only receivers; and in any case Charters Towers needed to receive the signals as early as possible on the approach. The satellite might have been equipped with a timing switch to turn on the transmitters, but the satellite team would have been loath to accept another potential source of unreliability. The main point is that the problem arose too late in the piece to solve it by rather radical design changes.
50. Reminiscence of D. D. Hardy of RAE in a letter dated 1 August 1984.
51. Adams.
52. Minutes of WRE post-trial meeting of 5 November 1971 on vehicle R3. File F5824/12/1.
53. Letter dated 1 November 1971 from Ian Gilmour, UK Minister of State for Defence. File A5877/2/1, part 2 folio 66.
54. WRE Director M. W. Woods in telex message of 11 November 1971. File F5824/1/2.
55. Minutes of Black Arrow WRE Planning Committee Meeting 42 of 25 February 1972. File F5824/1/2, part 7 folio 16.
56. K. Smith, BDRSS Work Report of August 1972.
57. Quoted from an article in RAE *News*, January 1977.
58. Quoted from an article in *Electronics Weekly* (London) 3 November 1976.

26 Run-down: *The End of the Joint Project*

FOOTING THE BILL 4: THE STONEHOUSE AND MASON AGREEMENTS

The joint project operated under the Thorneycroft Agreement for five years, from July 1962 to June 1967. As that period drew to a close it was very obvious that its replacement would require some tough decision making. For both partners, the eventual closure of the Range was no longer something over the horizon; a far distant event about which one might speculate but not take seriously in making policy. It had become something real, something actually to be carried through one day. For by the later years of the 1960s Woomera was moving inexorably into the first stages of decline. Still home to some 5000 people and with practically the entire workforce on the government payroll, it was costing $30 million a year to keep it running. Britain was still contributing a large part of this sum, and yet it was making ever-decreasing use of the Range facilities. It had recently accelerated its much publicised military withdrawal to west of Suez, and was collaborating more and more with its continental partners on short range weapons which could be tested adequately in Europe. Britain's own guided weapons research and development effort was narrowing down to the point where, at a pinch, it might dispense with the use of Woomera altogether after about 1970. For the first time it had adequate alternatives on its own soil. It could increase the safety area around the existing Hebridean range to make it suitable for testing short range and vertically launched weapons, or it could do as RAE was suggesting and build an off-shore launching platform at the Aberporth sea range in Wales.

Despite the best efforts on all sides it had not been possible to attract any substantial new customers for the Range to replace the failing British participation. It had been known since July 1966 that the ELDO program in Australia was not going to be renewed. After the great climax of the successful lunar landing in July 1969 the Americans, from whom so much was always being expected, were moderating their enthusiasm for space exploration and research. They had ended their first and only trials program at the Range, Sparta, with its successful appendix the launch of WRESAT, and had let it be known that future tests would be conducted at Kwajalein Atoll in the Pacific. The Japanese, who had an active satellite launcher project, had been vigorously courted; but they had proved deaf to suggestions that they needed a land range to augment their complex at Kagoshima, which fired over the sea.

With all these factors in mind Britain made the first move in the renegotiations by proposing, in March 1967, a thorough reshaping of the joint project. Henceforth, it suggested, Australia should become the sole owner of the Range. Britain would change its role from partner to customer, paying at the going rate for each series of trials. Britain recognised that this sort of transformation was not going to be easy for its partner, and it had no wish to force the disintegration of the Range. Apart from the moral obligations, Britain had further trials of the Royal Navy's short range Sea Dart to undertake at Woomera, as well as the evaluation trials of the Army's new mobile anti-aircraft missile, Rapier, described elsewhere. It accepted that the kinds of change it proposed could not be managed overnight. For the next few years, therefore, Britain volunteered to pay, in addition to its Range user fees, a diminishing portion of the running costs of Woomera and Salisbury.

Internal communications between the British Treasury and the Ministry of Technology on the question of the forthcoming renegotiation harp constantly on the theme of economies.[1] The Labour government of Harold Wilson was now determined to cut back on the current £5.5 million a year it was costing to support military and scientific facilities on the other side of the world—facilities which were now rapidly becoming redundant. A confidential memorandum, dealing with matters to be raised during a visit to London by Prime Minister Harold Holt late in 1967, sets the tone. Holt should be told, the memorandum suggested, that the Defence Secretary simply could not find money for Woomera on the current scale out of a stringently controlled defence budget. Holt should be thanked for Australian co-operation over the use of Woomera since the war, but reminded that the circumstances of the 1970s were very different from those of the heady 1950s. Unless an agreement with radically different terms could be arrived at, Australia would have to be invited to close down Woomera altogether.

Perhaps this puts too much stress on the intransigence of the British viewpoint, for there was still a fund of goodwill and generosity to draw on. The Ministry of Technology recognised that it would be unreasonable not to give good notice of any intention to withdraw; as one of its high officials put it, it would be unreal and unjustifiable to expect the full use of the Range up to the last minute and then have the staff sacked at midnight and all the buildings left to fall down. So, after some discussion, a temporary concession was arrived at. The Thorneycroft Agreement should continue for one more year, from July 1967 to June 1968, while negotiations were underway. Two slight changes were made. During the additional year, the project was billed for technical apparatus and equipment built in Britain; and the contractors on the Salisbury site were charged rent for their premises.

Meanwhile, what of the Australians' position? They were glumly aware that Woomera was doomed if they had to shoulder the financial burden alone. They believed that the British should continue to accept joint responsibility for the operation of the Range and if the workload fell to the point where it could not be sustained at all, then Britain as a partner in setting up the Range should share the responsibility and the great expense of closing it down. In addition, of course, from the Australian perspective far more was involved than the problem of what to do with the Range. It had to plan for the future of the whole Salisbury-Woomera complex which, thanks to the project, had grown into the largest conglomeration of scientific and technical resources in the country and the employer of 5000 staff, some of them narrow specialists not easily deployed elsewhere. The adjacent town of Elizabeth, which the joint project had helped to bring into being, was now a home to 50 000 people, and a good deal of its prosperity lay in the hands of WRE. If the retrenchments started to cut deep the political consequences could be alarming. About a thousand staff plus their families were at Woomera, and nearly all of them would have to be brought out and redeployed—or their services dispensed with.

At the same time Australia's defence planners could see some advantage in separating out the failing Range functions from WRE's research and engineering activities. To do so would bring the latter under national control and the spare staff and facilities could be redeployed into channels most advantageous for Australia alone. Such was the rationale behind an immense inquiry by a working party to catalogue all the current activities, resources and capacities of WRE insofar as they were working on joint project tasks, and to suggest how the resources might be directed towards Australia's defence needs. The services set up their own inquiry to see how use could best be made of the human and material resources at WRE released from joint project work.

In October 1967 representatives of the two partners met in Whitehall when the Australian proposals, based on the report of the working party, were put forward. Basically these amounted to regrouping the existing Establishment into three sectors. There was to be a R&D organisation at Salisbury which Australia would progressively take over entirely and harness to its own defence needs; a Range organisation which would undertake the remnants of joint project work and for which future operations would be planned in tandem; and a common services component, whose costs would be shared between the first two on an agreed basis. These measures would give the Australians maximum flexibility; for instance, they calculated that the Range organisation could be closed down at two years' notice, if necessary.

On the British side these proposals were well received, but there was more interest in cutting costs rather than just regrouping resources. They had practical suggestions on how this might be done: reducing the number of instrumentation sites at Woomera; dispensing with staff at Edinburgh Airfield and at the Giles station; more commuting to Woomera to reduce the numbers of families housed there; making Woomera an open town to cut the security bill. They also had some more general principles which they thought should govern joint project work in future. Only trials of guided weapons and rockets should be done with the retained equipment, no new facilities should be developed, and R&D work should be limited to that which improved the quality of WRE's support: for instance, better instrumentation or improved target aircraft. In future all costs should be shared, including those wholly borne by Britain and the costs of the air charter service. The project's activities should not be charged any more than a 'reasonable share' of the fixed costs.

Negotiations continued slowly between October 1967 and May 1968. The British High Commission in Canberra advised the Commonwealth Office to tread carefully. It would help 'to ease the strains that have resulted from recent United Kingdom decisions if we could reach a new agreement for partnership with Australia in defence and space technology' (probably a reference to the decision to withdraw from the ELDO program after 1971, which had not yet been announced publicly). A failure to reach agreement, the High Commission further warned, would greatly add to the concern over the British withdrawal of its forces from East of Suez. The negotiations should be viewed

> as an excellent opportunity to rebuild bridges between ourselves and Australia at relatively moderate expense. The Australians have already shown that they recognise our urgent need for economy. They are prepared to go a long way to meet us in reducing the future cost . . . There is however a danger that we may be tempted to press them too far.[2]

Presumably John Stonehouse, Minister of Technology, had these points in mind when he paid a visit in May 1968 to handle the final settlement, which was signed by himself and Senator Ken Anderson, Minister for Supply. (The next time Stonehouse left Australia some six years later it was under more ignominious circumstances. After staging his disappearance in Florida he was being extradited to Britain where he eventually drew a seven-year prison sentence on charges of fraud, theft and forgery.)

John Stonehouse, who as British Minister of Technology signed the 1968 agreement. (Hulton)

In its broad lines the Stonehouse Agreement followed the original Australian proposal. A Trials Organisation, later known as Trials Wing, at WRE was henceforward responsible for all project work in Australia. It became the Range authority, and its costs—broadly, the recurrent costs of running Woomera and the base support—were shared equally by the partners. All the additional 'special to project' costs of trials fell to the party originating them: the Range user. The other organisation, called 'Salisbury Laboratories' and consisting of the Engineering, Applied Physics, and the Weapons Research and Development Wings of WRE, were all-Australian. Any services the Laboratories supplied to Trials were charged for. However, to help Australia out with the cost of redeploying its resources now surplus to requirements, Britain paid it a total of $3.6 million up to June 1971. A couple of relatively minor points were that all immovable property of the project was transferred to Australian ownership, and the Edinburgh Airfield was handed over to the RAAF as an operational base.

The Stonehouse Agreement was a very significant step. Previously much the greater part of all the work being done at Salisbury and Woomera had come under the umbrella of the project, with the partners paying for it on a sharing formula which over the years had progressively shifted the financial burden on to British shoulders. Now, with the creation of the concepts of Range authority and Range user, the old relationship was transformed. The new arrangement took note of the British wish to move towards being charged as a customer of, rather than a partner in, Woomera. It brought closer the eventual Australian ownership of all the erstwhile joint project facilities. Over the next few years Trials Wing shrank and shrank away to almost nothing, while Applied Physics, Weapons Research and Development and Engineering eventually evolved with some name changes into the separate Laboratories of the Defence Research Centre Salisbury.

At a JPPAC meeting late in 1970 the Australian delegation suggested that talks about the future should be held as soon as possible. Generally the feeling on both sides was that there was no immediate need for changes to the Stonehouse Agreement of 1968, although Australia was adamant that it did not wish to take on any greater financial burden. It was left to the British to propose, in December 1970, an extension to the Stonehouse Agreement for a period of two years after it would have expired—that is, up to 30 June 1974. This was accepted and ratified by an exchange of letters between the British Minister of State for Defence Procurement, Ian Gilmour, and the Australian Minister for Supply, R. V. Garland, in October 1971. The same Agreement was later extended twice, for a total of two further years, until 30 June 1976.

For a time the workload at the Range picked up again—Sea Dart was still going and there were trials of the new Seawolf in 1971—but everyone recognised that it was temporary. At the meeting of JPPAC in September 1972, Britain advised that the work it could bring to

Woomera would have fallen away to almost nothing by the end of 1976. What trials work there was would probably be naval weaponry not suitable for Woomera. The services were tending to develop or buy together to save expense, and to do so in collaboration with other countries, particularly those of the Common Market. In future there would be fewer families of weapons and less testing generally.

This news was serious enough for WRE where, late in 1971, about 1250 people were employed within the large Trials Wing; it was even more serious for Woomera because all but about 220 of them were housed in the village and employed at the Range. The governmental response was to put in train a very thorough interdepartmental study of all the existing defence research facilities, to find out what exactly they were working on. The report of the joint project working party was submitted to JPPAC in October 1973 and the formal report in March 1974. Once the report was available both partners could plan for what was going to happen after 1976.

The formal report was delayed, but when it became available in July 1974 it was found that the interdepartmental committee offered three options for the future, and none of them boded well for the Range. The first was to close it entirely, leaving the village solely as the residential base for Nurrungar. The cost in 1974 dollars would then be about $2 million a year. The second was to reduce the Range and the joint project areas of the village to a 'care and maintenance' level, with the partners negotiating for a larger share of the village costs to come from the Americans. This would cost about $5 million a year. The third option was to continue to operate the Range as an Australian effort, at a cost of $14 million a year. The cost to Australia in each case would be subject to negotiation.

Lance Barnard, Australian Minister for Defence in 1974, who announced that Woomera would be run down. (PA)

It did not take the Whitlam government long to decide among these options. The decision was leaked to the media the day after it had been made and was widely publicised to the displeasure of both governments. On 17 October 1974, in response to a question in Parliament, Minister for Defence Lance Barnard spelt out what the future held for Woomera (in particular) after the current agreement expired:

> It is not correct to say that the Woomera Rocket Range will be closed down but it has been evident for some time that the workload for the Range after 1976 could not sustain the present level of operations there. The workload, of course, is primarily dependent on British requirements. It is not something over which the Australian Government has much control. The Government therefore has decided to run down Range activities after that date but to hold instrumentation and facilities in readiness for revival. The whole operation will require a great deal of administrative and technical planning and consultation with the British who are our partners in the Woomera project. Woomera village will continue to operate although probably at a reduced level. In particular, staff who may be declared redundant will be redeployed elsewhere in the Public Service.

Barnard's statement was received with dismay, and some sections of the media and the Opposition condemned it as a reversal of an election promise given in 1972. Woomera, it is true, had survived many predictions of its impending dissolution and the survival of the village itself was not in question this time. But the Range was still the livelihood of 900 staff and their families, and only a tiny fraction of these would be needed when its run-down to 'care and maintenance' status was complete. Soon rather wild rumours began to circulate about the future of Woomera: it was to be turned into a giant Army and Air Force base, or a centre for the oil and mining industry. Professor John Bockris, a lively American physical chemist at Flinders University, wanted to capture it for a more exotic use. Predicting wildly that within five years Australians would be wearing their overcoats in offices to conserve energy, he asked the State Premier for $20 million a year to found a solar station at Woomera using photovoltaic power to electrolyse water into hydrogen fuel. His importunities fell on stony ground and Bockris later returned to his homeland, bewailing the lack of local interest in solar energy.

At the November 1974 JPPAC meeting, led for the Australians by the Chief Defence Scientist, Dr John Farrands, the British were said to be eager to settle decisively their future participation in the project. Fortunately they found the Committee report acceptable and suggested setting up a joint working party to provide estimates of the cost of the run-down. A few remaining trials would not be finished until June 1978 but after that the Range could, as far as they were concerned, be closed. The working party reported in February 1975 that the cost of keeping the village running for the Nurrungar staff and running down the Range would be about $5 million a year, with another $3 million to finish the trials. The working party estimated that when the run-down was completed the village population would be about 2200, made up of 900 staff and dependants at Nurrungar and 1300 joint project and support staff and dependants. Since the population was currently about 5000, the size of the village would be halved.

A meeting between officials of the two partners was held in April 1975. Agreement was reached that all the costs of the run-down at both Salisbury and Woomera from the middle of 1976 onwards—the costs of surplus personnel, removal of surplus buildings, preventative maintenance, etc—should be shared equally, while the cost of retaining the facilities needed up until 1978 should be borne by Britain. Britain should complete the process, started in 1968, of transferring its equity in all the remaining joint project assets, and the new agreement would last for four years.

WRE completed the draft run-down plan for the Range and village early in 1976. It supplied a forecast for the work at Woomera after 1976; the staff levels needed up to and after 1980; target figures by which staff numbers might be reduced by redeployment and wastage at three-monthly intervals; details of what facilities should be retained and how it should be maintained; and, most important, estimates for the cost of the run-down plan. This plan formed the basis of the agreement signed by the partners in June-July 1976. It was named the Mason Agreement after Roy Mason, the Secretary of State for Defence at the time.

After 1 July 1976 Australia operated and funded the village and recovered the cost from all authorities conducting projects at Woomera—effectively the British and the Americans—in proportion to the number of employees of each project. The Range was renamed the Trials Resources Area and the village and its facilities such as the Technical Area and the airfield became the Woomera Support Area. Its main function, of course, was to provide accommodation and civic facilities for the Nurrungar personnel and, in a minor way, for the remaining joint project and Australian service trials. The RAF withdrew its last unit on Australian soil from the Edinburgh Air Base, where it had been since 1955, by lowering its ensign for the last time and presenting it to the RAAF officer in charge.

As the run-down proceeded Britain made it clear that it needed no more trials work after 1980 and did not wish to contribute any further to running the Range after that, not even to keep it ticking over on a care and maintenance basis. A closing-out agreement was negotiated in January 1980, defining, among other things, how the natural environment of the abandoned parts of the Range was to be restored; and at midnight on 30 June 1980, after a life of thirty-three years, the joint project formally terminated. In London, where it was lunch time, toasts were drunk at the Naval and Military Club by General Evetts and other pioneers of the Range.

CONTRACTION AT SALISBURY

During the first half of 1974 a policy of reducing the staff of the Trials Wing to suit the vanishing workload at the Range came into effect. For the first time 'redundancy', a concept which had practically vanished from sight in the Public Service in the 1960s and early 1970s, was being discussed around the tea trolleys.

At Salisbury the knives cut deep. One of the first casualties of the contraction was the Space Research Group inside Aerospace Division. It consisted of a small group of enthusiasts under Dr David Robertson, and had gradually come to concentrate on pure astronomical research. Even its friends found it hard to make out its defence significance. Just before it was abolished, Space Research suffered a bitter blow when the Department of Supply advertised for tenders to demolish the 26 metre parabolic reflector and tower at Island Lagoon near Woomera. This great radio telescope had been used to send commands to deep space probes like Mariner 9 when it was close to Mars, to prepare it for orbit. It closed on 22 December 1972, after tracking the Pioneer 10 spacecraft en route to Jupiter. After NASA declared it surplus to requirements, Robertson was greatly disgusted when the Department of Supply refused to accept it as a gift, on the grounds that it would cost too much to run it as a pure research facility. (A similar station at Johannesburg was offered to the South Africans, who accepted with alacrity.)

The Public Service Board accepted that it had to find other work for the redundant staff wherever possible, and it also undertook to consult the unions before putting any measures into effect. When the government changed at the end of 1975, however, the fate had not been clarified of those staff who were redundant and yet could not be reassigned to other work. The newly elected Fraser government did nothing at first to allay anxieties over this particular issue. The incoming Minister for Defence, James Killen, left the question open in his statement to Parliament of February 1976. He did no more than confirm that the Range was to be reduced to a care and maintenance level by 1980 and the staff of Trials Wing would be reduced by some 700. Later Killen told a press conference:

> The fact of life is that the bulk of work at Woomera is governed by British participation and the level of British activity has gone down. There is simply nothing this Government can do to maintain Woomera in its present state in the absence of joint activity.[3]

The simple measure of not replacing the Trials staff lost through normal attrition served to reduce the numbers engaged on joint project work from 1170 in June 1974 to 820 at April 1976. The following month the government advised a delegation from the United Trades and Labour Council of South Australia that about 380 of these would be declared redundant over the next three years. The officials of the peak union councils CAGEO and the ACTU[4] were of course eager to see this reduction achieved by voluntary transfer or retraining.

After a survey of staff opinion at Salisbury in which it was made abundantly clear that most wished to retain their present posts at Salisbury or Woomera with very few even willing to contemplate a transfer in the same area, the Public Service Board clarified its principles for identifying surplus staff. As many volunteers as possible would be retrained or retired, and the rest selected on the basis of 'relative efficiency'. However, in some categories, particularly of the industrial grades, length of service was to be the main criterion of efficiency.

Early in February 1977 letters went out to all the staff of Trials Wing informing them whether or not they were being retained. At this stage wastage had reduced the number of surplus personnel to about 170. Regularly updated lists of names of the surplus staff and their qualifications were circulated throughout the Department of Defence across the country so that when vacancies arose suitable excess staff from Salisbury or Woomera could be considered.

In the event the outcome was not nearly as disastrous as had been predicted in some quarters. All surplus staff were either dissipated through natural wastage or absorbed into other government employment—almost always at Salisbury. When the last British trials under the project ceased in 1978, a further fifty-six people became superfluous, but this time all of them found new work at Salisbury. No one was dismissed, but a small number had to accept demotion and others transfer to elsewhere in the Public Service, including interstate in a few unfortunate cases.

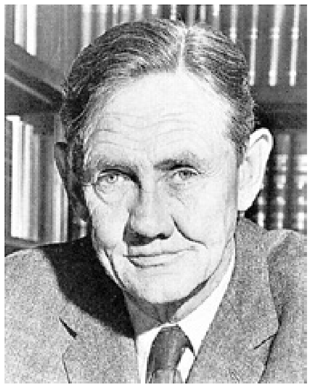
After 3 April 1978 the Wings ceased to exist and were replaced by four separate Laboratories (Electronics Research, Weapons Systems Research, Advanced Engineering, and Trials Resources [the last was soon afterwards absorbed into Advanced Engineering Laboratory]) and an Administration Branch. The position of Director was abolished and the heads of the Laboratories and the Chief Administrative Officer formed a Management Committee whose chairmanship rotated among them. The Salisbury area was renamed the Defence Research Centre Salisbury—but this was merely a shared address, not an establishment. The Laboratory Heads now answered directly to the Chief Defence Scientist in Canberra, the Department of Defence having taken over responsibility from Supply (including for the residual joint project work) in 1974. This transformation marks the point at which the old Establishment shook off its divided origin and its successors took up their roles within the Defence Science and Technology Organisation as specialists in Australian-only problems of telecommunications, surveillance, computer technology and weapons systems.

A NEW ROLE FOR WOOMERA

Woomera had faced a clouded future before but, Micawber-like, had always said that 'something will turn up'. This time, however, all the signs seemed to be negative. In November 1968 some of the townsfolk were briefly excited by predictions from a soothsayer that an unspecified disaster would shortly overtake the town. Some people even began to ring up the hospital to ask about its emergency plans, and the Roman Catholic, Anglican and Uniting Church chaplains joined forces to inveigh against irrational fears born of gossip, boredom and ignorance. No doubt real worries about the future of the town played their part in this curious outbreak of superstition in a place where one might least have expected it.

But, as fortune would have it, the optimists were again vindicated. This time the rumours that the Americans would be Woomera's salvation, so often repeated over the past twenty years, proved for once to be accurate. Woomera was selected as the base town for the Joint Defence Space Communications Station, Nurrungar[5], which was to be built a short distance out of the village. This was a timely decision indeed, for the establishment of Nurrungar was nothing less than the salvation of Woomera. By becoming in effect the civilian support centre for the station, Woomera took on a new role and its economy was revitalised by the lavish injection of USAF funds. As the joint project work fell away to nothing the Americans were persuaded to more than triple their original payments to Woomera.

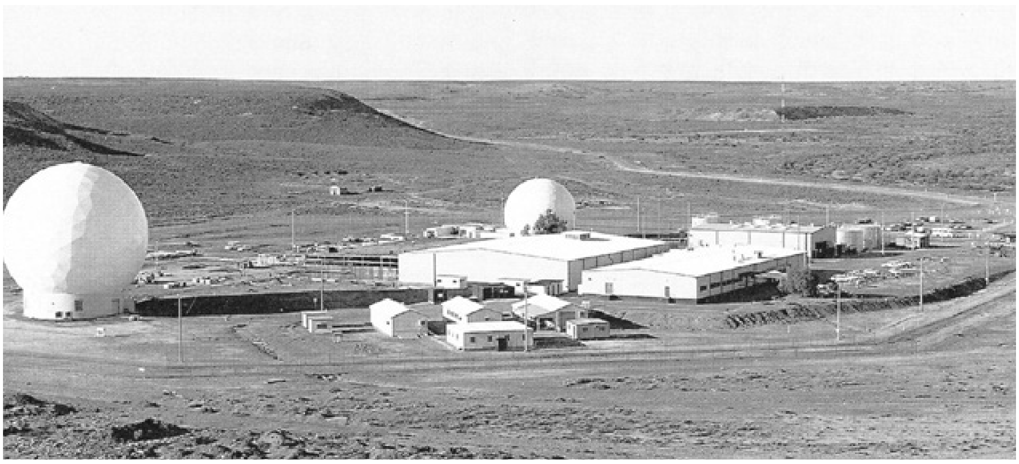
The first step in the foundation of Nurrungar was the visit to Woomera in August 1968 of a party headed by Col R. J. Duval, Chief of the Air Defense Systems Office USAF, whose job was to examine a number of potential sites around Australia for the establishment of a military satellite communications centre. Some seven months later a second visit headed by a Dr Yaramovitch, USAF Pentagon, came to gather some extra information about Woomera and to enter into an agreement with the Australian government. The decision to establish Nurrungar was announced publicly on 23 April 1969, when the Liberal Prime Minister John Gorton explained amidst considerable controversy that his government had accepted the American proposal to establish the station. Construction was to start in September 1969 and the station would be operating by late 1970.



John Gorton, Australian PM 1968-71. He announced in 1969 that the Nurrungar base was to be established. (PA)

Nurrungar went on to become one of the three most important 'joint facilities' on Australian soil, the others being at North-West Cape in WA (commissioned in September 1967) and at Pine Gap, 26 kilometres southwest of Alice Springs (established by an agreement of 9 December 1966). For practical purposes Australia is geographically opposite the United States and having stations there, on the territory of a friendly nation, offered a convenient means of filling in the gaps of the global network of communications and reconnaissance which is vital for the defence of the United States and its allies.

The purpose of Nurrungar was given in very broad terms in Prime Minister Bob Hawke's statement of 6 June 1984, when he told Parliament that both it and Pine Gap receive information about missile launches and nuclear explosions from space satellites. Its exact functions cannot be described here, and they are in any case irrelevant to this history.



An aerial view of the Nurrungar site.

THE CONSTRUCTION OF NURRUNGAR

Nurrungar was eventually built about 19 kilometres from Woomera village, in a small depression surrounded by low hills next to the crumbling ruins of an old staging point for coaches between Adelaide and Alice Springs. Although according to an interim report, 'the site selected protects against seaborne jamming threat and offers partial protection against airborne threat', this would have been equally true of many other sites in inland Australia.[6] In fact the saucer-shaped depression had a knoll some 9 metres high over the building site, which had to be entirely removed. However, the logistic advantages of choosing Woomera were obvious enough. The personnel of the joint project naturally became involved in the planning, especially in expanding the village facilities. At first no one at WRE was sure exactly

Don Freeman

US Ambassador Walter Rice. (Trevor Dallen/John Fairfax & Sons, 1968)

what the Americans would need to operate the station, but matters became clearer in May 1969 after a survey party headed by Colonel Jerry Flicek visited Woomera. Flicek worked for the USAF's Space and Missile Systems Organisation (SAMSO), whose job it was to oversee the construction of the station and to bring it into operation. He had a formidable task, not least because in accordance with USAF practice he was given almost sole responsibility for bringing it to fruition; only rarely did he need to have a decision authorised in Washington. The choice of Flicek was excellent in that he had previously lived in Woomera, having been in command of the Sparta project, and under his friendly but firm command Nurrungar was completed in time.[7] As the key Australian man, the Department of Supply put forward the amiable and discreet Don Freeman, who had just finished a spell as Station Director of a NASA tracking station in Queensland and before that had been deeply involved with the Range telemetry systems at Woomera. Freeman was therefore used to working with Americans and had exactly the right sort of technical background.

Had the will of the electorate been different, Nurrungar might well have foundered at the planning stage with critical future consequences for Woomera. For 1969 was an election year. The hostility of the Australian Labor Party, or at least of its left wing, to 'American bases' on Australian soil was strong at the time; and since the agreement would be binding for the next decade the Governor-General and chairman of the federal executive council, Sir Paul Hasluck, declined to sign it until after the election. Once the Coalition was returned to office there were no further hindrances, and on 10 November 1969 the agreement was signed by the US Ambassador, W. R. Rice, and the Minister for External Affairs, Gordon Freeth. Despite the delay in formalising the agreement some work on the station was able to proceed. The Adelaide office of the Department of Works set up a project team headed by Ian Bickerstaff and he, together with one of his team, John Slater, and Alex Gray from WRE, visited America to obtain preliminary design information. Gray and Slater stayed for several months and passed all the necessary design information back to Australia. By the time the agreement was signed plans were advanced sufficiently to call for tenders for the main construction contract. Worth $3.7 million, it was awarded to A. V. Jennings Industries in December and the firm began work the next month. It constructed the two main buildings (one for operations, the other for administration), the antenna base, the guardhouse and other minor facilities. To the total costs of construction, Australia contributed $1.5 million, this being the agreed ceiling figure. By April the antenna structure was complete and, despite some delays caused by strikes, the technical building was complete enough by July 1970 for equipment to be installed, and this was quickly followed by the administration building. By the beginning of October the main contract was substantially complete except for the powerhouse which was an addition to the main contract. The speed of construction was remarkable considering the difficult terrain and the remoteness of the site.

The building contractor had provided what amounted to a number of empty shells in which the equipment was to be housed. Most of the equipment which went into Nurrungar was, naturally, American; and Flicek had a number of US contractors to help him with its installation, the main one being the big electronics company Philco Ford. The antenna structure and its radome, a large dome of fibreglass protecting the antenna within from the weather and prying eyes, was so large and heavy that it had to be shipped from the States to Port Adelaide, and thence to Woomera by road. Most of the rest of the equipment, though, was flown in direct to Woomera on a number of C141 Starlifter transport aircraft. In order to turn it all into an operational system a tremendous amount of interconnecting cabling and wiring had to be laid and this was undertaken by WRE's Engineering Services Group under Joe Kilgariff.

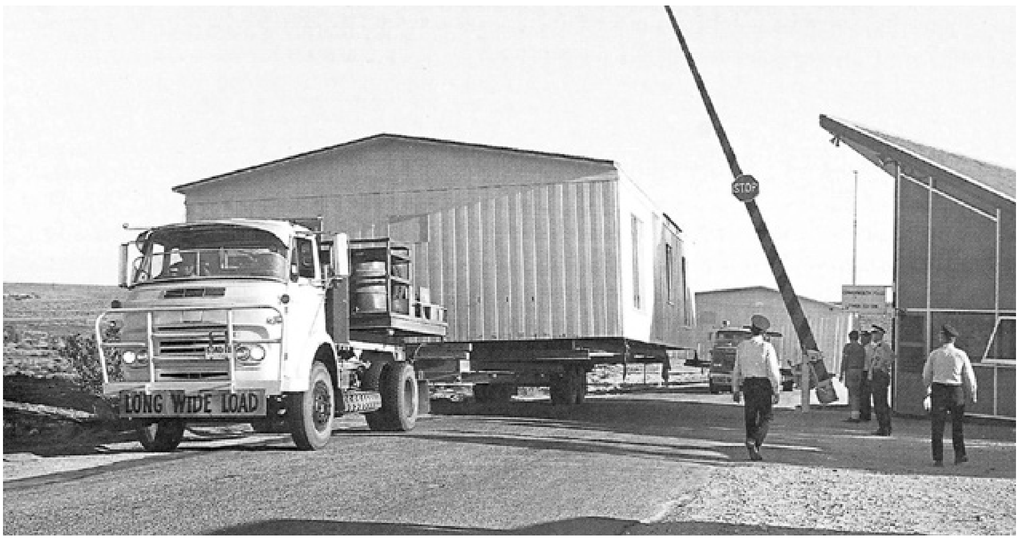
During the early phases of the project Flicek and a small staff of about five were located at Salisbury, close to Don Freeman and his Nurrungar Management Group. In April 1970 Flicek and his staff moved to Woomera, where they were temporarily housed in Hangar 3 in the Technical Area. As more and more staff and equipment arrived from the US, this quickly became inadequate. Fortunately this was at the time when the Department of Works, after a stay of over twenty years, had decided to withdraw from Woomera West, and the USAF were able to take over their premises. At first the support staff for Nurrungar—clerks, typists, cleaners, drivers—were drawn from Salisbury and Woomera, and the village messes provided a catering service. This arrangement was not very satisfactory to either side, and it was not long before the Department of Supply arranged a contract with Amalgamated Wireless Australasia, a firm already active at the Range, to provide the necessary staff. This contract was later increased in scope to provide technical personnel, and between January and June 1971 about thirty-seven AWA technicians were sent to the US to attend specific training courses, and two of these topped the courses they were on. In addition nine Australian servicemen were trained in the US to operate the equipment, and all of them worked with the USAF personnel at Nurrungar to form a joint operational team. Early in 1974 Fairey Australasia was successful in winning the follow-on contract to provide support to the station and have maintained it ever since. Most of the staff simply changed employers.

THE VILLAGE AND NURRUNGAR

In its first years Nurrungar, and by extension Woomera, faced an uncertain future. Whether the former was to survive at all seemed doubtful, for the Labor government which came to power in 1972 was forthrightly hostile to the station's existence once the original lease had run out. In a statement to Parliament in April 1974 Prime Minister Whitlam stated unequivocally that his government intended to adhere to the ALP policy that no foreign military bases, stations, or installations should be allowed on Australian soil: 'we honour agreements covering existing stations [but] we do not favour the extension or prolongation of any of those existing ones.' This was commonly interpreted to mean that the Nurrungar agreement would not be extended after it came up for review in 1978.[8] However, a year and a half later the Whitlam government reversed its policy. It now said that the agreement on Pine Gap, due to expire shortly, would be extended. The Minister for Defence, W. L. Morrison, explained the change of heart by saying that the facilities were now genuinely under joint control and Australia was now being properly consulted.[9]

PM Gough Whitlam. His ALP government reversed its earlier opposition to Nurrungar. (PA)

Nurrungar station itself had no housing, and although the joint project was beginning its long decline living space in the village was still tight. Only eighty housing units could be made available for the Nurrungar personnel. The USAF and their contractors were allowed only a certain proportion of married staff and likewise the AWA contract included a clause which allowed only an unaccompanied posting. At the time there were about 350 personnel, excluding dependants, associated with the station, both US and Australian, and this number increased and reached a peak of almost double that before declining. The worst period came at the latter half of 1971 when USAF personnel of the Aerospace Defense Command, the organisation scheduled to take over the permanent operational responsibility, began to increase in numbers. An additional eighty-one houses were supplied by Sigal Industries, a South Australian firm, and the first of these pleasant, well-made transportables arrived at Woomera at the end of April 1972 and thereafter at the rate of about three per week. The Woomera population began to drop sharply about this time, and soon the shortages were replaced by the problem of deciding what to do with whole streets of empty and decaying houses. Fortunately single accommodation was not so critical, although it had its problems too. So that the night shift at Nurrungar could sleep comfortably during the hot summer days, the USAF provided air- conditioning. This caused something of an outcry of favouritism towards the Americans from other Australian Range users and employees.



The first convoy of Sigal transportable houses for USAF personnel arrives at the Pimba gate.

The American administrators of Nurrungar were far from happy about the leisure pursuits available at Woomera, particularly when its staff were working unusual hours; it thought that at a minimum it should install a bowling alley, a gym, a day room, an auto repair shop and a hobby shop for woodwork and ceramics—at its own expense. Flicek wrote to Area Administrator Duke in December 1971 pointing out that the influx of his countrymen 'has dramatised the lack of suitable recreation facilities in the Woomera area . . . most activities are centered on a set eight to five work day with every weekend free'.[10] WRE's Director Woods was broadly sympathetic to these wishes, though he had reservations about the day room. The departmental policy was firm that Woomera should continue to be an Australian owned and managed town, into which the Americans were expected to integrate themselves thoroughly. For this reason it wanted to see no separate domestic or recreational development either at Nurrungar or in the village. The day room idea, harmless though it seemed, might help to produce an 'Americans only' enclave inside the village, which would certainly be deleterious to such an isolated community.

When Nurrungar Commander Carl Hagen followed through by putting in a formal request for a six-lane bowling alley (a size which the station could not sustain under the usual regulations), he left his superiors in no doubt that he regarded Woomera as a hardship posting. Apart from the private clubs, there were, he pointed out, only two places of public entertainment in Woomera, the pool and the theatre. The nearest small town was 180 kilometres away over 'a treacherous dirt road'. Worse, 'there is no television . . . the radio station is a five watt subsidiary of the ABC. The programs are stodgy and dry with very little popular music.'[11] Hagen and his staff put up a valiant fight for the new facilities and had actually obtained most of the gear for the bowling alley by the end of 1974. WRE played its part by modifying some buildings for hobby pursuits, but in April 1975 the projects were cancelled because the money for the alley building was not forthcoming. The wood and auto hobby shop planned at Woomera West area was never used, and eventually became a maintenance shop for household appliances. That November the USAF had sadly to auction off six complete bowling lanes, a trophy case and 107 pairs of used bowling shoes.

During the original negotiations to establish Nurrungar a stumbling block had been the Americans' wish to include a commissary where duty free goods, especially liquor and tobacco, could be bought. The Americans argued that all their military had this right: it was regarded as part of the pay, and providing familiar items always helped maintain morale in an isolated posting. They gave assurances that the outlet would be small and carefully controlled to nip any black market in the bud. The Australians on the other hand argued that good supplies of all necessary goods were available through ASCO—a bold claim, this—and that profits on drink sales both there and in the messes were used for facilities which the Americans had full use of. Eventually the agreement over Nurrungar was signed without the position being properly defined, especially over the supply of liquor.[12] The commissary privileges soon came into effect, so that in 1972 the American Nurrungar staff were able to buy four bottles of spirits a month per person for a modest $2-$4 a bottle, and a case of beer a week for less than $3. Naturally this arrangement, once known, produced a certain amount of hostility and jealousy among the other residents, and they were not slow to complain about it. 'The people who spoke to me are resentful that there is a privileged section of the community which is getting the best of two worlds', reported the Acting Area Administrator, and the generous availability of alcohol brought him more direct problems:

> Inevitably some of their 'parties' get out of hand and we are involved in false alarm fire calls, recharging fire extinguishers, and repairs to quarters. On occasions their activities are transferred to the Mess building, usually in the small hours of the morning.[13]

The loss of sales certainly contributed to the store's decline, but to be fair the amenities supplied by the Americans more than offset the loss of income to the Board. The situation eventually came to be more or less accepted in Woomera, especially as the Americans were fairly circumspect about their privileges.

The several hundred Americans who were living at Woomera by the time the joint project ended could not fail to give it a new cultural definition. The Fourth of July celebrations became one of the most popular events in the social calendar. The newcomers formed new clubs to cater for their special interests. A softball and baseball diamond were laid out on the Newman oval and flood lighting provided. Many more children came to the village and the USAF paid for the school to be enlarged and for the curriculum to be modified. The Americans also brought a new angle of vision to the Woomera Board, and of course the

The USAF contingent at the Fourth of July celebrations in Woomera, 1988. (Doug Champion)

influx of US dollars revitalised the Woomera economy. Most problems of integration were small and in general relationships between Australians and Americans have been very good, despite the rapid turnover of personnel attached to Nurrungar. While controversy continues elsewhere about whether stations such as Nurrungar really serve Australian interests as much as they do American, the remaining Australians at Woomera seem happy to trade off the small and officially admitted risk of becoming a nuclear target for the continued survival and prosperity of their town.

WOOMERA AT THE END OF THE PROJECT

The coming of Nurrungar greatly ameliorated the situation at Woomera; indeed, it is hard to see how the village could have survived in the post-project years without it. Five years after the project had finished, Woomera in its role as an Australian Defence Support Centre gave employment to only 222 people, who, with their dependants, totalled 420. By contrast, Nurrungar supported 1056 people. The other services of the village, such as the store, the schools, the churches, the police, Telecom and the Bureau of Meteorology added 145 to the workforce. One in three of the population was a US citizen.

Even so, the American presence could not compensate for the gradual but relentless withdrawal of Range work up to 1980. The working assumption had been that the population would bottom out at about 2400. In fact it had fallen to 2279 in the last year of the joint project and subsequently it fell continuously with each passing year, reaching 1791 by the end of 1985. Obviously the population could not decline to nearly one-third of the peak figure in 1967 without serious effects. The financial problems which started to confront the Woomera Board from 1971 onwards with the failure in profitability of the AFCANS store have been described in Chapter 13, and they were exacerbated by a loss of trade to the chain stores once the Stuart Highway leading south was sealed and Port Augusta an easy two hours' drive away. The transport facilities were curtailed or cut altogether. The Budd railcar ceased to run. The Fokker Friendship charter service was cancelled in 1979, and with it went the residents' opportunity to get to Adelaide cheaply in standby seats. The local railway station closed and parcels had to be collected from nearby Pimba.

The shrinkage of Woomera had a dismal effect on the infrastructure and even the appearance of the village. The abandoned, ruinous dwellings, some with every ground floor window broken by children, gave the place a most dilapidated appearance for some years. A sensible plan was formulated to allow the village to shrink uniformly around its perimeter and keep the centre intact. Unfortunately this could not be done very systematically, for the brick houses started to suffer a sudden and dramatic deterioration. The local bricks from which they were made had not been of very good quality in the first place; nor did they rest on adequate foundations. Now the walls and ceilings of many houses began to crack and subside. One cause was probably that the surrounding ground, kept artificially moist for many years, was now drying out and shrinking as the gardens reverted to desert. As the run-down progressed further, unsightly gaps like bomb sites appeared in the hitherto neat village townscape, such as those caused by the demolition of the Staff and Senior messes. Woomera West, the bustling Works camp which had been there from the beginning, was practically deserted. Out towards the Technical Area and the Woomera Airport the roads were lined with dead and dying trees as the watering rounds were no longer sustained. It was hardest for the elderly people who had lived out their mature years at Woomera and now found it difficult to adjust to the shrinkage of the town and its new and very different role.

As for the Range, the coming of Nurrungar had nothing to offer it. Clearly it could not survive in anything like its original form. The service chiefs were asked to look at it in the light of their requirements through the 1980s; but there was not a great deal of interest, at least initially. The Army wanted to develop some small artillery sighting rockets and it needed a desert exercise ground for its Leopard tanks, but simple space and comfortable base facilities were more important to it than an elaborately instrumented range. The Air Force wanted a place for some weapons trials, and eventually perhaps would need to garner some information by telemetry and tracking from short range surface-to-air missiles. It was not a great deal, and certainly not enough to prevent the virtual dissolution of the Range. And so it contracted dramatically from more than 20 000 square kilometres to less than a thousand. Hundreds of sites and buildings were demolished or abandoned. All of the launching sites were stripped until nothing remained but the concrete pads. Only Range E survived even partially intact, and even that was reduced to a bare relic. The little village by the edge of Lake Koolymilka near the rangehead was bulldozed to its foundations. Evetts Field, where Jindivik had flown, was virtually abandoned, with its control tower and other buildings sold off and removed. At the rangehead itself only the right-hand launching lobe, LA2, was retained along with its underground Equipment Centre. The other became derelict, filled with kangaroo droppings, old piping, girders and scraps of sheet metal. Even the Instrumentation Building was partly emptied of its equipment.

The virtual demolition of the Range was carried through with a thoroughness and a gloomy enthusiasm which shocked some of those who had worked there in its palmy days. Some thoughtful observers of the process saw that psychological factors were playing their part. The destruction was overseen for the most part by elderly WRE officers whose entire careers had centred on trials at Woomera. Since they were forced to acknowledge that the monument to their efforts could not survive intact whatever they did, it was as though they wanted to obliterate the whole structure, to bring it all down in a Samson smash before they themselves passed into retirement. They were largely successful, although the Range did continue on a greatly shrunken scale. A certain amount of equipment survived the

Koolymilka village during demolition. The substantial building in the background was a dining hall where the large Range staff had their meals.

depredations of the run-down (though some of it now has almost an antiquarian appeal), and the Instrumentation Building was even modestly refurbished. Two separate radar tracking stations and a number of the Contraves posts were retained, although the posts are used infrequently enough to demand protection against vandals in the form of a high barbed wire fence. Regular campaigns from Salisbury lasting a few days still go up four or five times a year for small services and scientific trials of one kind or another.

By the mid-1980s much of the physical evidence of the early and middle years of the joint project had been expunged from Woomera village. Nearly all the brick houses had vanished or were slated for demolition. The 'Silver City', the streets of old Econos, Hawksleys and Riley-Newsums, had been sold in two big auctions, the battered prefabs carted away to start new careers as holiday shacks somewhere along the coast. All the messes had gone except for the large comfortably ugly building which is now the combined restaurant, pub, hotel and disco for the village. To the residents this place is just 'ELDO'. Most of its habitués have forgotten, if they ever knew, that its name was originally the acronym of a space enterprise of boldness unimaginable in Australia today.

Yet as befits an organism planted in a tough environment, Woomera village has proven tenacious of life. It is by no means a slum or a ghost town. The new housing is much more attractive than the old, and considerable sums of money have been spent on the school and on renewing the pipeline. Most of the infrastructure survived the worst period of contraction fairly unscathed. Woomera still has all the usual community services of a town of its size: hospital, dentist, fire brigade, churches, banks, pharmacy, hairdresser, store, TAB agency, post office, state police, service stations, kindergarten, primary schools and high school. The clubs and societies—from soccer to lawn bowls, from pistol shooting to philately—still flourish, if not on the former scale. As far as its purpose permits, Woomera is now thoroughly civilianised. The post of Range Superintendent was abolished with the departure of Captain F. E. Irvine, and an Area Administrator is now the unofficial mayor. Woomera Board survives with the help of funds derived from the ELDO bar profits. Its nine members—six elected from the community and three nominated by the Area Administrator—still operate the theatre, the pool, the youth centre and the library, and regulate the business franchise holders with more than a show of democratic participation. The Secretary of the Board still edits *Gibber Gabber*. Communications are not too bad either. Those who can afford it can still fly to and from Adelaide on one of the scheduled flights of the small commercial Kendall Air. Access by road is better than it ever was in the project days and, now that the town is open to all, visitors pass through regularly on the bus services to Adelaide and the north. For its size the village offers residents as much if not more than is generally found in communities of similar size elsewhere in Australia. In the slightly longer term, say more than ten years, the future of Woomera is uncertain. But then, except during the short periods of rapid expansion, it always has been.

Notes and Sources

1. My account of Britain's approach to the Stonehouse agreement rests heavily on Ministry documents supplied by W. T. S. Pearson.
2. Cable 'Joint Project Negotiations' from the UK High Commission Canberra to the Commonwealth Office London dated 1 March 1968.
3. 'Woomera to go into mothballs', *Advertiser*, 19 February 1976.
4. CAGEO: Council of Australian Government Employee Organisations (now amalgamated with ACTU). ACTU: Australian Council of Trade Unions.
5. Its official title is 'Joint Defence Space Communications Station Nurrungar'. However, it is universally referred by the last name alone, said to mean 'to hear' in an Aboriginal dialect (according to Steve Hemming, the Curator of Australian Ethnology at the South Australian Museum, 'Nurrungar' is a variant spelling of the tribal term applied to the Aboriginal people of Yorke Peninsula, the Narrangga) Letter of 28 October 1986).
6. 6. Telex of 26 May 1969. File N6116/10/1.
7. 7. Colonel Flicek became Nurrungar's first Commander. After returning to the US in April 1972 he retired from active service life, having been decorated by the President for his services.
8. 'Whitlam undertakes to axe two key US defence bases'. *Financial Review*, 4 April 1974.
9. Quoted in 'Policy change over all US bases', *Advertiser*, 23 August 1975.

10. Memo of 7 December 1971. File N6116/2/4 part 1.
11. Comments from a requisition of October 1972. File N6116/2/4 part 1.
12. Submission from Research & Development, Department of Supply to the Minister for Supply dated 1 July 1970. File 5628/1/5.
13. Memos dated 2 June and 1 December 1972 from the Acting Area Administrator to WRE's Deputy Director Trials Wing and the Chief Administrative Officer respectively. File 5628/1/5.

27 Epilogue

The joint project belongs to history now. Looking back over it, what can we say it achieved? One answer, of course, is that it gave a lifetime's secure employment to several thousand young engineers, technicians and administrators. For them it is sufficient that their paymasters thought their labours important at the time, and few of them are interested in looking any deeper. They married and raised their families on the project, and for them that is its 'value'. But this will hardly do for the historian. His job is to render up the final accounts, not least to the taxpayers who settled the bills. One can ask whether the achievements met the original objectives and, if not, whether this reveals bad planning or signifies a sensible shift of aim with changed circumstances. One can inquire further how far the residual and indirect benefits of the project may still be detected, nearly a decade after it ended, and whether it has had consequences for good or ill which were no part of the intention of its original architects.

It must be conceded at once that Woomera and the joint project of which it is the most visible remainder were originally founded on a misreading of the immediate future, in two respects.

The first misreading was a semi-political one. It was that a strategy of a united Empire defence could be meaningful after 1945. The experience of the blitz and Britain's coming nuclear vulnerability gave rise to a scheme (originating with Lord Alanbrooke and Tizard) for dispersing armaments production, stores and skilled labour overseas, on the assumption that whichever area of the Empire or Commonwealth might be attacked in the future the others could supply weapons and supplies to help the threatened realm. In such a scheme the peculiar joint contribution of Australia and New Zealand was to become a production area specialising in guided weapons. Not only were they to build and store them; in the relative isolation of Australasia ever more powerful and sophisticated weapons were to be developed and tested by indigenous industries, seeded with talent and know-how from Britain. In short, in the hyperbole of the time the region was to become the 'arsenal of Empire'.

The Alanbrooke-Tizard plan was a transient and, even at the start of the project, a somewhat fanciful scheme. No uniform defence strategy could have been long imposed on the British Empire. In 1945 and 1946, when the project was being planned, Britain still had its colonies in Africa and Asia, and was the senior partner among the dominions of the British Commonwealth: Australia, South Africa, Canada and New Zealand. This 'white' Commonwealth had obvious ties of blood and affection and it is plausible that its members might have fixed on a common policy for a while, pooling their resources, armaments and research effort. Yet, even as the project took shape, the Empire was dissolving into the 'new' Commonwealth: India and Ceylon as the first members, then Ghana and Malaysia, then the great rush of the former West Indian and African colonies; so that more than thirty new members had been admitted by the time the project ended. This 'new' Commonwealth could never have had a defence policy which embraced many of its members. The very first full year of the project's operation, 1947, saw the blood-letting which accompanied Britain's withdrawal from India, thereby proving that Britain could not even guarantee its former subjects security against each other. The following year Britain withdrew from Burma, Ceylon and Palestine; Malaya became a federation and Eire withdrew from the Commonwealth. One of its founding members, South Africa, was edged out of the Commonwealth in 1961; in the same year, two of its members went to war with each other and have been hostile ever since. Other members have become one party states or tyrannies, such as Uganda under Amin. For Britain and the loyal ex-dominions the biggest shock of all was Suez (1956), where an emerging nationalist leader successfully defied two of his erstwhile masters, Britain and France. An historian reflecting on the meaning of Suez for Britain has put it elegantly:

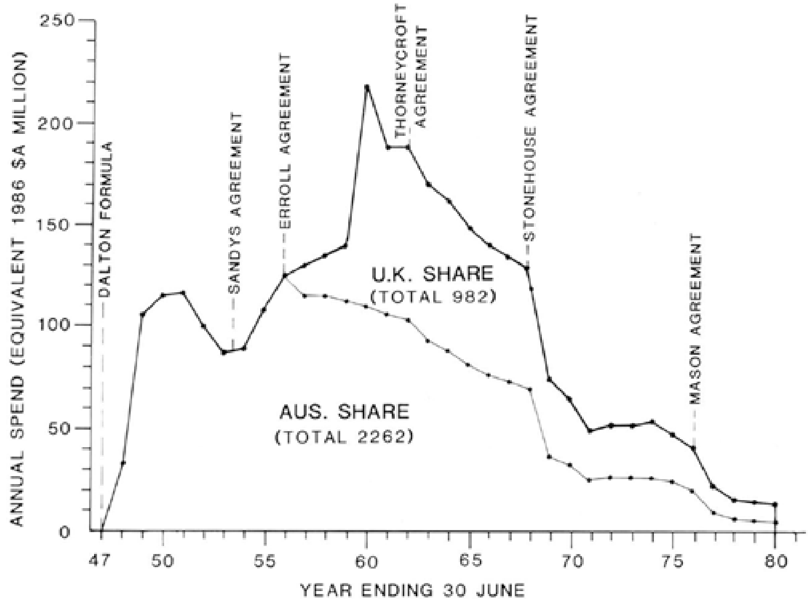
> The Commonwealth, apart from Australia and New Zealand, had not supported her; had indeed rejected and judged her. She was not even a Great Power in the terms of the Cold War. What the Russians could do in the streets of Budapest, Britain could no longer do in the

bazaars of Port Said or along the salt waters of the Canal, once her lifeline. She was simply one medium power among many, and the realisation was to play its part in leading her away from the concept of Commonwealth in search of an older identity in Europe.[1]

The idea of an imperial defence policy, of which the project was one manifestation, was therefore a fiction well before the 1950s ended, and was tacitly recognised as such later on when the Wilson Labour government withdrew from East of Suez, the better to meet its NATO obligations and to help maintain the balance of power in Europe. This became the first priority demand on the British forces. Partly in response to this, and partly to serve its own ends, Australia entered into ever closer co-operation with the United States as its main ally in the Pacific, and this weakened even further the original intent behind the project.

The second false assumption was a technical one. It was the supposition that the defence plans of Britain and therefore of Australia depended critically on the foundation of a long distance land range. Just as Britain wanted, and was compelled, to go it alone over nuclear weapons, so did a combination of pride and fear encourage it to do the same in providing its own elaborate facilities for a weapons range. But as we have seen, the plans for powerful transcontinental guided weapons were scrapped even while the Range was being built. When they were revived in the mid-1950s, they lasted for only a few years before the final and decisive cancellation of Blue Streak. That event was significant enough in Britain, where it gave rise to soul searching parliamentary debates as bitter as those of the Suez crisis four years earlier; but it was equally significant for different reasons in Australia. For it marked the end of the honeymoon of the project. The original sense of complete harmony which had prevailed throughout the 1950s was lost with the demise of Blue Streak, which in retrospect looks like the real watershed in the history of the project.

But of course the project survived Blue Streak by twenty years. After the demise of that weapon, just as before it, the work undertaken at Woomera was extremely varied. About 13 000 separate trials were conducted there, of all sizes and functions. The rockets experimentally fired on the Range ran the gamut from the primitive RTV1 to the mighty Europa. There were over 500 assorted upper atmosphere research flights, including 200 or more Skylarks. Six satellites were boosted aloft, of which two achieved earth orbit. There were many other tests of military equipment, ranging from ninety high-altitude parachute drops to six trials of an ejector seat. About 3500 bombs were dropped on the Range specially set aside for them. The money expended on the project at Woomera and Salisbury by the two partners is a meaningless figure in everyday language: it was at present values something like three and a quarter billion Australian dollars[2], and this is not allowing anything for the British costs incurred in Britain for developing and producing the hardware used in Australia. By and large, and despite its redesignation near the beginning as a 'general purpose' rather than a 'long range weapons' range, Woomera did vindicate Tizard's prediction that it would attract work as a magnet attracts iron filings.



This graph shows the year by year expenditure on the joint project by both partners. adjusted for inflation. Australia's share was 70% of the total.

It might be argued, though, that Tizard's magnetic metaphor is hardly correct. Much of what was done at Woomera did not call for its unique qualities (especially its location), suggesting that work was not so much 'attracted' there as pushed on to it. At the extreme, it might be argued that, despite the changed requirements after the first couple of years, too much money and rhetoric had been expended on Woomera to make it politically feasible for either government to cut its losses and get out. At work too were the imponderable factors of sentiment and individual will. Although the joint project was conceived and born of two governments of the Left, throughout the long period between 1950 and 1966 it flowered under a conservative Australian government headed and ruled by one man, Sir Robert Menzies, whose ties with Britain were undoubtedly sincere but were at best romantic and at worst verged on the sycophantic. It would be absurd to claim that the prosperity of the project over these sixteen years of optimum achievement was due to Menzies alone. Menzies's role in the British atomic tests was so dominant that he arranged almost singlehandedly for them to be conducted in Australia.[3] He played no such central role in the project—a much more diffuse affair—but we may certainly suppose that he gave it his full blessing, and to have Menzies's blessing was no mean thing, considering his total domination of his party. The British could hardly have wished for a more understanding ear than Menzies's. This was the man who relished his appointment as Constable of Dover Castle—a title which, however empty, did make him symbolically responsible for defending his beloved England's traditional bulwark against invasive attack.

THE DIRECT BENEFITS: TO BRITAIN

No cost/benefit analysis of the joint project to Britain can be attempted here even in outline. Of the costs disbursed at home, little can be said except that they were certainly heavy. Over the three full decades of the project (1950-1980) the total 'military burden' which the British placed on themselves was double Australia's; a loading which has had, so some economic historians aver, severe and permanent repercussions on the country. More specifically, we can say that Woomera was one of the children of Britain's greatly increased expenditure on military research and development straight after the war. The amount spent on R&D, as a proportion of total military spending, rose from 9.3 per cent in 1949-50 to 13.3 per cent in 1956-57, with the actual amounts being £69 million in the former year and £204 million in the latter.[4] In the early years a good proportion of this money must have been spent on development and testing facilities for the first generation of guided weapons, and on manufacturing the prototypes flown at Woomera. But no accurate overall assessment of the cost of the devices tested at Woomera and Salisbury to the British taxpayer is available, and perhaps the figures do not exist in any collated form.

The author is entirely unqualified to say what the lasting value of this expenditure may have been. He cannot say whether the people of Britain can sleep more easily in their beds, or hold their heads higher with pride, as a consequence of what their government did at Woomera. The evaluation of British defence research and space technology since World War II must be left to other and sharper pens than this, and certainly nothing definitive can be done until the records are opened more widely than at present.[5]

Something may be said, although necessarily in the vaguest terms, of the benefits to Britain of having Australia as its partner. The successive waves of trainees from Australia were a modest source of fresh and vigorous brainpower in a country whose intellectual resources had been tasked to the limit during the war years. As the trainees spread out among the various British research establishments they had to be properly taught. They were there to learn; and when they went home they would be applying what they had learnt to Britain's advantage, as well as their own country's, so good planning for several years ahead was essential to get the most out of them. Later on, when British trials teams began to go to Australia, the discipline of sending them away from home with their equipment crystallised the planning and clarified the problems of operating away from the design team. The trials were therefore a test of the weapons under something akin to operational conditions, and the need to liaise constantly with the partner gave a focus and an urgency to the evolving guided weapons research.

The return of the first wave of trainees to Australia, supplemented by seconded British staff moving the other way into Salisbury and Woomera, gave a very useful nucleus of staff by 1950; and over the succeeding few years the first air-to-air and surface-to-air guided weapons were given full scale practical tests at Woomera. These short-range weapons were the first major achievement of Britain's post-war military R&D program, and although the facilities of Woomera certainly had not been planned for that purpose they were instrumental in bringing the new weapons into service. Possibly these weapons could have been tested entirely in Britain, and even if the distinctive advantages of Australia had been deemed indispensable—the ample space, the visibility, the isolation from observation and the easy retrieval—they could have been met in a hundred more accessible places around the Australian coast without Woomera. This was much less true of the second generation of guided weapons, especially Blue Steel, which needed a large and superbly instrumented range; and Woomera was the natural home for the big rocket projects like Black Knight, Skylark, Blue Streak and Black Arrow.

There were other minor gains: a long program of aerodynamic research in the supersonic and hypersonic ranges, with more of the wind tunnel work being done in Britain and the free flight trials in Australia. There were investigations into aircraft damage and general GW anti-aircraft effectiveness, and here the Australian theoreticians contributed a good deal.

THE DIRECT BENEFITS: TO AUSTRALIA

During its lifetime the joint project cost the Australian taxpayer over two thousand million dollars in current terms. In the context of federal expenditures this is not a large sum: the country spends roughly this amount on defence every four months at present. And the Defence Department today is spending more annually on scientific research and development than it ever paid into the project, except during a few peak years of the late 1950s.[6]

Still, what did the Australians get for their money? One undeniable benefit was some additional foreign investment. Australia's participation in the project persuaded Britain to inject funds equivalent to almost a thousand million dollars into the economy and so provided, directly and indirectly, thousands of jobs over the years.[7]

If the proof were forthcoming, the greatest benefit of all, though an intangible one, would naturally be that the project served to deter aggressors. Those aggressors were never more than potential. Throughout the project, as today, Australia is one of the most secure countries in the world. It has faced no direct military threat for more than forty years, not even at the level of harassment or raids. It is practically inconceivable that the country will confront an invasive attack in the foreseeable future, and for any nation apart from the superpowers to mount one would be a highly visible preparation of years. The prudent defence strategy for Australia is therefore a form of 'fire insurance'; that is, its defence expenditures are really premiums paid to cover the small risk of hostile actions in the future. Was the substantial part of the premium which went into the project well spent? Was Australia made more secure in its position on the Asian rim of the Pacific, as a result of the billions poured into the shared activities at Woomera and Salisbury? We have the bare fact that, while it ran, neither partner was embroiled in a military conflict threatening to its domestic population; and both survived the three decades of its span with their sovereign integrities intact. Unfortunately history does not permit controlled experiments. It is therefore impossible to say what part the project played in that happy outcome. There is no hard evidence that it played any.

The overt reasons why the Chifley government entered the project were described in Chapter 1. From a later perspective, and looked at coldly without all the emotional commitment to the 'Mother Country', the reasoning behind the project was rather curious. What sort of defence strategy and weapons requirements could a small, populous, highly industrialised island country just off the European coast possibly share with an isolated, underdeveloped, continental-sized nation on the edge of the Pacific? But Chifley and his ministers could never have seen matters in quite that light. The offer was compelling enough in the context of the time; indeed, it is arguable that Chifley would have been culpable if he had rejected the British approach. From this distance we can see that his acceptance expressed two rather contradictory impulses. One impulse, taking into account the changed post-war political circumstances around the Pacific, where the Japanese collapse might be expected to introduce a power vacuum into a volatile region, was to knit the country more firmly into a system of Commonwealth defence which in optimistic theory might amount to a global third force. The other impulse, based on bitter wartime experience, was to take a more independent stance: to build up an armaments industry more sophisticated than hitherto, capable of producing the new weapons as they were developed. As a partner in the project, the country would draw on British know-how and benefit from the emigration of the British armaments firms or their offshoots, as predicted in the 'arsenal of Empire' scenario.

In theory the price of Australia's contribution should have been a remarkable bargain, especially during the expensive period when clever negotiation limited Australian indebtedness to a fixed ceiling sum. Under the terms of all the joint project agreements, Australia had full access to the experimental data obtained at the Range and also full rights to production plans of the weapons tested. This principle was guaranteed by the administrative arrangements, especially by the representation on CUKAC and JPPAC, and it was honoured. While with the British atomic tests Australian officialdom, not to mention the public, was not fully informed, this was not the case with the work of the project, it was a full collaboration.

Such a reservoir of knowledge, placed freely on tap by one of the most inventive and resourceful nations in the world, would have been priceless if Australia had persisted in its plan to create an indigenous missile and (later) a space industry. But with a few rather minor exceptions this never happened. There was no single reason, but perhaps we should see the watershed event as being the great reorganisation at Salisbury in 1955, which was deliberately designed to reduce the influence of the British partner. Though it was done for reasons good to the Australian authorities, it probably discouraged many British firms from setting up design teams in Australia. It also meant, as far as MoS was concerned, that Australia was judged henceforth by the success of its performance in taking on and providing answers for the R&D topics it did choose from the program provided in London. In the event, the productivity of this work was very slender, and MoS fell back on using Woomera as a pure test range with all the design work staying at home. It could perhaps have been different: a period of seven years with Pritchard running the whole R&D effort and with the weapons program being controlled through the project arrangements, might have attracted UK design teams to take root in Australia. This would have left Australia in a much stronger position for independent growth later on.

Whatever the exact mix of reasons, then, the planned transfer of technology did not happen. The direct military value of the joint project 'bargain' to Australia therefore depends heavily on how far the varieties of guided weaponry tested at Woomera matched Australian defence needs. If the match was not good, Australia, far from getting a bargain, was actually subsidising its partner's military program.

We can at once point to one excellent match: the target aircraft, Jindivik. Jindivik was developed from scratch jointly in both countries to meet an identical need; it did all that was required of it; it was progressively improved over the entire span of the project; and, though by 1987 it was nearing the end of its life, it was still in use by both ex-partners for testing current weapons.

But Jindivik, however praiseworthy, was a special case: a means to an end. Can we say that, as a direct result of its participation in the project, Australia obtained new, effective, thoroughly tested weapons which matched its political and geographical circumstances? Did it gain weapons with a long service life, superior in performance to those available from any other arms supplier? The answers to all these questions must be 'no'. For one reason or another, almost none of the British weapons over which Australian technicians and engineers sweated for years at Woomera and Salisbury ever found favour with their own armed forces. The RAAF did not buy a single one of the small air-to-air guided weapons which the RAF ordered: neither Fireflash, Firestreak nor Red Top. When, in the late 1950s, the RAAF wanted a small missile for its Avon/Sabre plane it looked at Firestreak and then bought the American Sidewinder, after proving it was cheaper, more practicable and more easily installed. About the same time the RAAF wanted a ground-to-air missile to guard its air bases. It did choose the British Bloodhound, but the US Nike- Hercules had strong support and would certainly have filled the role. The RAAF never expressed any interest in the nuclear-tipped Blue Steel, for which such sophisticated instrumentation was- provided at the Range. And the other two services were, if anything, even less enthusiastic. The RAN had no interest in Seaslug, Sea Dart or Seawolf. The Australian Army did not need the ground-to-air Thunderbird. For reasons which were no doubt valid, it rejected the Malkara anti-tank weapon after Australian R&D effort—hard cash and scarce expertise—had been expended on developing it for the British Army. Then again, after trying out at Woomera both the American infantry weapon Redeye and the British Blowpipe, the Army preferred to buy the former. Like many other armies elsewhere, it did buy Rapier after that excellent weapon had been developed and tested at Woomera. But Rapier has been a straight commercial success: British Aerospace has sold it to many friendly countries, none of which found it necessary to host its development trials before putting it into service. If Australia got any *special* advantages in deploying Rapier as a result of having participated in its development first, they remain obscure.

As for the Australian endeavour, it resulted in the development of just one guided weapon system under the joint project: the anti-submarine missile Ikara, which has been in service with the RAN ever since the mid-1960s and with the Royal Navy and the Brazilian Navy since the early 1970s. It is now a formidable weapon, and one that is still being upgraded regularly. But Ikara was a unique success, and even for Ikara the Woomera facilities were convenient but far from essential. It was convenient to do some developmental trials on land, as described in Chapter 17, but for an anti-submarine weapon sea trials could not be long delayed. As far as is known, the considerable later evolution of Ikara has never been handicapped by the absence of the Range.

Britain's independent deterrent, and all the work on warhead re-entry problems which surrounded it, was by far the most costly of the shared enterprises. Yet its direct value to Australia was negligible. Even Australia's hosting of the atomic bomb tests made more sense than its agreement to provide the Lake Hart and Talgarno facilities. For in the early 1950s it was not impossible that the country might one day wish to possess nuclear bombs, which it had the resources and the technical competence to manufacture, and for which it could have produced or bought the delivery aircraft. Intermediate range ballistic missiles were another matter. The purpose behind the work with Black Knight and Blue Streak was very dubiously relevant to the defence of Australia, at least at the point reached when it was given up. Nor is this only a retrospective judgment. As early as 1957, just after a cost ceiling had been put in place under the Erroll Agreement, one powerful voice within the Menzies Cabinet was querying the value of allowing some of the best scientific brains in the country to accumulate unproductively at Salisbury and Woomera, where apparently (he said) they were aiding the very slow development of some not very remarkable weapons.

Certainly one thing could have entirely justified the huge Range extensions and the costs of training its staff in the arts of handling large liquid fuelled rockets. That would have been the lasting success of the big space projects of the 1960s. Had the efforts of ELDO been successful and, even more, had the satellite launcher facility been retained in Australia, the key achievement of the joint project would not be a matter of dispute. But Europa was not successful, nor did its successor stay in Australia. (The government of the day did its best, but in retrospect the failure to relocate Europa II at Darwin, thereby presumably putting in place a permanent internationally financed satellite launcher, was probably the biggest lost technological opportunity this country has ever suffered.) Instead, the teams, equipment and expertise so painfully built up through the 1960s were allowed to disintegrate as soon as it was realised that any future effort would have to be at Australia's own expense. With the great contraction in NASA's activities around the world, with ELDO's disappearance and Britain's abandonment of an independent launcher, the truth stood revealed: the government was not willing, or could not afford, to capitalise on even the odd little triumph of WRESAT. Woomera, for all the rhetoric about the town's becoming 'the Cape Canaveral of the Commonwealth', was essentially a parasitical growth, drawing its support and nutriment from elsewhere. Once detached from its host, it withered and shrank at once. As far as Australia was concerned, apart from the temporary jobs it created and the flow of foreign funds into the country, ELDO and Black Arrow were so much wasted effort. Neither of the ex-partners now has any independent route into space of the sort which the joint project seemed on the verge of offering for a few years; but again it would be difficult to indicate any really deleterious consequences of abandoning such ambitions.

Taken all in all, the *direct and enduring* military benefits of the project must be assessed as insubstantial. The failure to find a continuing use for the Range meant, unfortunately, that its capital equipment—buildings, workshops, plant, an airfield, launchers—built up so laboriously and expensively over three decades and largely demolished at the run-down were of no lasting benefit. Similarly, the expertise so painfully acquired in launching big liquid propellant rockets has been entirely dissipated. The whole delicate web of instrumentation, communications systems, trained staff and all their support facilities which constituted the Range in its heyday was pulled to pieces and thrown to the winds. The work of destruction was done so thoroughly that in the unlikely event that Australia ever wished to produce its own long range weaponry, or develop the hardware of a space launcher industry, it would have to start again nearly from scratch.

Some of the foregoing has been revealed only with the passage of time, but by no means all of it. In 1967, on the eve of the major reorganisation which brought the very survival of the Range into question for the first time, a senior officer of WRE was tasked with making an assessment of the military achievements of the project. Given the circumstances it may be assumed that he left no corner unexplored, yet his report only ran to a scant four pages.[8] Clearly he was disconcerted by the paucity of hard evidence for the project's having increased Australia's military strength:

> The simple fact is that Australia has not used to any worthwhile extent the facilities open to her under the joint project to develop and test her weapons of war . . . It cannot be denied that this vast reservoir of knowledge and practical experience has for many years been largely ignored by the Defence and service Departments.[9]

The author refused to allow that the costs of the project were being wasted, however. He argued that if nothing else it was good public relations, serving to strengthen Australia's ties with its important allies. He thought that in the eyes of the world the Woomera complex and the much-publicised space activities being conducted there stamped Australia as a technologically advanced nation, capable of defending itself, if necessary, with the most modern weapons.

The passage of time has not been kind to such special pleading. The Woomera Range, and the project itself, could not have been essential to the security of the country, for, despite all the admonitions, the Range did almost cease to exist; and the consequences have not after all been so alarming. The geopolitical region of which Australia is part is less volatile today than it was fifteen or twenty years ago, but the reduction in tensions has been due to quite extraneous causes which have nothing to do with Australia's military posture. Neither the country's prestige nor the safety of its population have been discernibly weakened with the ending of the project. Is Australia in the late 1980s less efficiently armed, and more susceptible to aggression, than it was twenty years ago when it was helping Britain develop the most advanced weaponry of the day? That would be hard to argue. Probably a better case could be made for the opposite proposition: that Australia's defence posture has grown more attuned to contemporary realities and more confidently self-reliant over the last few years.

Even if the partners had never embarked upon their collaboration it is safe to say that the Australian armed forces, like those of every other industrialised state in the world, would have equipped themselves somehow with guided weapons. They would have bought them on the open market or imported them under arms agreements with other countries, chiefly of course the United States. They would have set up some sort of proving ground on which to evaluate them, but this could have been of modest size. Not one of the weapons which Australia has in service now, or has ever had in service, has required a range in the far outback on the scale of Woomera. With a little judicious expansion, Jervis Bay, or even the Port Wakefield artillery ranges just outside Adelaide, would have easily sufficed. Some trials, such as those of the indigenous Ikara anti-submarine missile, would then have had to be done differently because the down-range instrumentation would have been lacking; but the difficulties would not have been too serious and could have been overcome.

It was the ambitions of the United Kingdom which brought Woomera to birth, and when those ambitions changed course the Range decayed. The proof of that is surely the lack of much Australian service interest in the Range during the life of the project. Since the wants of society are infinite, spending on defence, like all other public spending, is the art of allocating scarce resources. For much of the project Australia was also participating in regional security pacts: ANZUS, SEATO, the Manila Treaty, ANZAM. Such pacts have given the assurance, or the apparent assurance, of support from powerful neighbours, but they have imposed expensive obligations. They have demanded the maintenance of well-equipped forces at a high level of readiness, which put pressure on the Defence vote and caused more critical looks at scientific research and development which contributed little to the immediate need. In peacetime Australia the defence budget is rather inelastic. Money spent on the trials of sophisticated hardware at Woomera could not be spent on servicemen:

the price of a destroyed Jindivik was not, generally speaking, available for spending on boots, rifles and radios. Was it sensible to let the project eat up those scarce resources? Many a service chief, starting with Sir Thomas Blarney in 1949, has vented his irritation that 'airy-fairy' research at Salisbury was swallowing up funds which could have been better spent on basic new equipment for the nation's soldiers, sailors and airmen.

INDIRECT BENEFITS TO AUSTRALIA

What of the indirect and less quantifiable advantages of the project? Though it is hard if not impossible to gauge its importance, the project did cause a flow of scientific and technical brainpower and people talented in other directions into South Australia. Some of them settled permanently and enriched the community as a result. A related benefit was that the project afforded Australian scientists and engineers the opportunity to work alongside their British, European and American counterparts, and this was a more treasured opportunity in the early days when people of ability were less internationally mobile than they are today. It must be admitted, though, that in the national context these effects were small. The total number of skilled staff who came to Australia directly as a result of the project was tiny in comparison with the overall results of the energetic migration program of the 1950s, and especially the recruitment of university staff from overseas.

Although the project did not lead to any wholesale transfer of British defence industry to Australia it did induce a number of firms to establish subsidiaries or branches at Salisbury. There were ten or more major contractors at the height of activity, and others had periodic work. The original scheme to transfer much of the technical development to industry was not always successful; for example, in the case of precision optics the production runs were too small and discontinuous for the small firms involved. Only four of the contractors on the Salisbury site—Fairey, British Aerospace, Hawker and Thorn EMI—survived the closure of the project. By this time all were thoroughly Australianised. One of them, Fairey, had gone further and had fully detached itself from its parent. It became locally owned and operated entirely within South Australia. Back in 1948 the British company had sent a team to Salisbury to support its aircraft used by the RAN (the Firefly first and later the Gannet), and to be a Range user at Woomera. The Fairey staff brought with them a host of specialised industrial skills rarely seen in Australia, and went on to play a vital part in the target aircraft services at the Range. Later Fairey handled the production runs of the specialised target cameras developed by WRE. Eventually it left the Contractors' Area for new premises elsewhere in Adelaide, but it continued to design and manufacture equipment, much of it in the electro-optics field, to Defence contracts. It was also a versatile jobbing engineering company and developed products for specialised civilian markets: computerised teaching aids for handicapped children and scanning systems for geophysical survey companies are two examples. Since 1974 most of the Australian technical representation at Nurrungar has been in the form of the 150 Fairey staff. This meant that by 1986 Fairey had had a longer continuous presence at Woomera than the joint project itself, of which it was a solid and valuable relict.

Another benefit to the State (and to Western Australia too) was that the requirements of the Range stimulated and even financed, the improvement of telecommunications in the outback, and helped to open up, for good or ill, a lot of inaccessible terrain. Then again, good scientific research into the ionosphere was done at Woomera which could not have been done otherwise; but it had to be done in the cracks, as it were, of approved joint project work. The government refused funds to the Academy of Science more than once for a separately funded research program.

A further side benefit is that Woomera, because it existed, was easily transformed into a convenient dormitory settlement for the Nurrungar station, which has since become its chief and almost its only role. Nurrungar benefited from the presence of the village, but it must be said that it was convenient rather than necessary to Nurrungar. Had Woomera never existed, an equivalent of it would not have been created from scratch; any one of several outback towns could have served as host, and probably at lesser expense to both Australia and the United States, because such a town would have been an economically viable entity in its own right, and not one requiring permanent governmental largesse to keep it alive.

To the natural question 'How long can Woomera last?' it is not possible to give any satisfactory answer. This much can be said: while the Nurrungar station remains, Woomera township will survive. And because Woomera is there, the Australian services will find some use for it as a convenient centre for desert exercises, for bombing practice over Lake Hart and for small rocket proving trials. Some limited tourism and mining activities in the area, especially Western Mining's venture at Roxby Downs, may inject new money into Woomera's economy.

The Nurrungar facilities are unlikely to be permanent, however. 'It would seem', concluded a Joint Parliamentary Committee on Foreign Affairs and Defence late in 1986, 'that over the coming decade, the Nurrungar ground station will no longer be required except perhaps as a back-up facility.'[10] The Committee recommended that alternative uses for the station should be explored in good time. It suggested, rather vaguely, that it might be converted into the ground base of an all-Australian satellite system in conjunction with over-the-horizon radar and airborne early warning aircraft to provide surveillance of the northern approaches.

A more immediate possibility is that the RAAF will take over control of Woomera. It still sponsors occasional trials there and has shown interest from time to time in acquiring some of the remaining facilities of Range E and the Technical Area. The RAAF and to a lesser extent the Army also use parts of the residual Woomera Prohibited Area for military exercises. What is left of the prohibited area is a good stretch of desert whose use for such purposes is not at present a matter of public concern. It is valuable to the RAAF because its other ranges do not enjoy quite the same advantages of space and security. The area can be used for bombing practice, for testing the latest generation of air-to-air missiles against towed targets, for the advanced tactics of electronic warfare—both defence and attack. If the Department of Defence were to relinquish its right to control access to the area, an equivalent could not easily be found elsewhere. No matter how remote the region proposed, it is safe to predict that in the present climate a multitude of special interest groups would energetically oppose the acquisition. Therefore the RAAF has reason to be grateful to the project.

If the RAAF did take control, no doubt a number of servicemen would need to live in the village. The number would be small, though, and it is hard to see how they could compensate for the withdrawal of American support, if that should ever happen. Could the village survive as an urban entity if its population fell very much more? It might be more economical to close it down finally and house the RAAF personnel in the thriving Roxby Downs township now rising only 80 kilometres away. In such a case the legend might be tested that the village was built over the biggest opal deposit in the world.

Drawing back from these conjectures, we have left to last the least questionable of the indirect benefits. It is indisputable that the project did serve to accelerate the formation of a competent defence science staff throughout Australia. This was the nucleus of the present Defence Science and Technology Organisation (DSTO), unified in 1975 to provide a working support to the armed services and to a lesser extent to local industry. The efforts of the DSTO are now directed to goals relevant to Australia's distinctive needs; needs which are (arguably) now being defined more realistically than formerly. The achievements of this staff and their predecessors over the lifetime of the project were in part technically innovative—for example, it developed from nothing methods of mathematically modelling the performance of guided weapons—but it also introduced ways of costing and managing its undertakings. Some of those people are still within the Department of Defence, and have stamped their impress on it. The technicians involved in the work at Woomera acquired the discipline needed to work with high explosives and toxic and dangerous chemicals. The rigour of the safety procedures is demonstrated by the remarkably few work-related accidents during the whole life of the project.[11] Furthermore, the expertise in rocket and gun propulsion, aeroballistics, data reduction, fine mechanisms, advanced optics and electronics developed at Salisbury did not evaporate. It was inherited by the current DSTO laboratories there, and has flowed to some degree into most of the current all-Australian projects.

The most important of these is the over-the-horizon radar Jindalee. When they are in operation radars like Jindalee will offer a new and most desirable facility: the constant surveillance of the air and sea approaches to Australia out as far as 3000 kilometres. Over-the-horizon radars (OTHR) are such key components of the 'defensive denial' strategy enunciated in the Dibb Report of 1986 that Dibb recommended the construction of an operational OTHR network, and this was accepted by the government when it authorised project definition studies.[12]

The pioneers of radar during the war had realised that, although the high frequencies they were using were normally restricted to lines of sight, under certain unpredictable conditions transmissions bounced off the ionosphere could bring back to the receiver useful information about objects—ships and aircraft—far beyond the horizon. The US Naval Research Laboratory conducted experiments throughout the 1950s into OTHR and had a powerful system called MADRE working by 1958. During projects Gaslight and Dazzle at the beginning of the 1960s a WRE physicist, John Strath, headed a small team at Woomera armed with its own radar to investigate ionospheric echoes, and he was given access to the Naval Research Laboratory's work. The technology of Jindalee has multiple origins, including advanced computer signal processing techniques, but one strand of its development grew out of the tripartite research programs based on the Black Knight launchings at Woomera.

Project Winnin was another example of continuity. Winnin was an active expendable decoy rocket, to be fired at sea from a ship up to at least the size of a destroyer. Winnin was capable of hovering, spinning on its long axis or moving in any direction, while an electronic payload picked up the radar signals from an attacking missile and transmitted new confusing signals of its own, luring the missile away. WRE's Propulsion Division did some work on the single solid motor by adapting the Ikara design, although later the propulsion unit was put in the hands of Maribyrnong. Winnin itself was not taken into production, but work on an electronic warfare system for ships continued as a collaborative effort with the US Navy.

Other fainter traces of influence from joint project work can be detected in Barra, the Mulloka sonar system and current electronic warfare techniques generally. The Barra passive submarine detector consisted of a buoy dropped into the sea from an Orion aircraft. A sonar sensor underwater picked up submarine engine noise which was transmitted to the circling aircraft. Barra started life as an item under the joint project and a few trials were undertaken at Woomera. After 1980 it continued as a collaborative Australian-United Kingdom enterprise under a distinct Memorandum of Understanding and by the mid-1980s it was in production.

Military research among the Western allies is becoming more and more a group enterprise. Those who draw from the common pool are expected to contribute to the pool: the United States, though it has been generous to Australia in the defence field, established that principle a long time ago. It was in the days of the project that Australia paid its dues and got its 'entry permit'. It benefited from the Mutual Weapons Development project and, of course, such international programs as Gaslight, Dazzle, Sparta and Aerobee could be hosted only by reason of the Woomera facilities. Their existence helped the country to gain access to some of the most carefully guarded defence circles overseas. Australia shares in the Technical Cooperation Program with fellow members America, Canada and Britain, as part of NAMRAD (Non-Atomic Military Research And Development).

In this sense the project did not so much close down as mutate into other forms of co-operative defence agreements. As the Menzies era fades into the past, trailing behind it all its outmoded assumptions and loyalties, we must learn from history, husband our resources, and adopt a defensive posture more in keeping with Australia's position—both literal and metaphorical—in an uncertain world.

Notes and Sources

1. Edward Grierson, *The Imperial Dream: the British Commonwealth and Empire 1775-1969*, Collins, London, 1972, p.284.
2. In constant 1986 dollars. A full breakdown of the costs disbursed in Australia is as follows:

WHAT THE JOINT PROJECT COST THE PARTNERS

	Actual costs*			Present-day costs#		
	Aust share	UK share	Total	Aust. share	UK share	Total
'The Dalton Formula'						
1947-48	2.6		2.6	33.5		33.5
1948-49	9.0		9.0	105.4		105.4
1949-50	10.1		10.1	114.8		114.8
1950-51	11.8		11.8	116.1		116.1
1951-52	12.1		12.1	98.9		98.9
1952-53	12.4		12.4	87.0		87.0
1953-54	13.4		13.4	89.4		89.4
1954-55	16.2		16.2	107.8		107.8
1955-56	19.1		19.1	124.2		124.2
'The Erroll Agreement'						
1956-57	19.0	2.3	21.3	116.3	14.2	130.5
1957-58	19.0	0.6	19.6	113.8	3.7	117.5
1958-59	19.0	4.6	23.6	111.7	27.3	139.0
1959-60	19.0	18.7	37.7	109.8	108.6	218.4
1960-61	19.0	14.5	33.5	106.3	81.2	187.5
1961-62	19.0	15.5	34.5	103.5	84.5	188.0
'The Thorneycroft Agreement'						
1962-63	17.0	14.3	31.3	92.9	77.9	170.8
1963-64	16.2	13.6	29.8	88.2	74.0	162.2
1964-65	15.2	12.7	27.9	80.6	67.6	148.2
1965-66	14.9	12.5	27.4	76.1	63.8	139.9
1966-67	14.7	12.3	27.0	73.1	61.4	134.5
1967-68	14.7	12.3	27.0	70.2	58.8	129.0
'The Stonehouse Agreement'						
1968-69	8.0	8.0	16.0	37.5	37.4	74.9
1969-70	7.2	7.2	14.4	32.7	32.7	65.4
1970-71	5.6	5.6	11.2	24.7	24.6	49.3
1971-72	6.3	6.3	12.6	26.0	26.1	52.1
1972-73	6.7	6.7	13.4	26.1	26.0	52.1
1973-74	7.5	7.5	15.0	26.5	26.5	53.0
1974-75	7.8	7.8	15.6	24.1	24.0	48.1
1975-76	7.6	7.6	15.2	20.4	20.4	40.8
'The Mason Agreement'						
1976-77	3.9	5.4	9.3	9.2	12.9	22.1
1977-78	2.9	4.6	7.5	6.2	9.7	15.9
1978-79	2.6	4.9	7.5	5.2	9.5	14.7
1979-80+	2.3	4.7	7.0	4.1	9.3	13.4
TOTAL	381.8	210.2	592.0	2262.3	982.1	3244.4

* The annual amounts paid at the time, converted to $Am at the exchange rates then current, to nearest $Am 0.1.
\# Converted to 1986 Australian values, in equivalent $Am.
\+ Estimated.

3. 'The Royal Commission received no evidence to disturb the overwhelming impression that the original decision to lend Australia to the United Kingdom for the purpose of the latter's nuclear tests program was taken by Australian Prime Minister Menzies without reference to his Cabinet.' *Report of the Royal Commission into British Nuclear Tests in Australia*, AGPS, Canberra, 1985, 1, p.7.
4. Figures cited by Malcolm Chalmers, *Paying for Defence: military spending and British decline*, Pluto Press, London, 1985, pp.24, 113. The 'military burden' (defined as the proportion of GNP devoted to defence expenditure) averaged over this period 6% in the UK and 3.1% in Australia.

5. British commentators have not been so reticent, however. This is how matters appeared to David Divine, the respected Defence journalist, in 1964, about mid-way through the project: 'the waste of scientific and technical effort and the expenditure of what must be considerably in excess of £300m appears to have produced only a fringe benefit and to have prevented production of weapons that might well be more essential to Britain's security . . . It seems unnecessary further to labour the point or to do more than list the other scrapped weapons like Pandora, PT428, Blue Boar, Red Rapier, Blue Sky, Red Dean, and the rest. It seems necessary, however, to say that the three British services today have only the three anti-aircraft missiles, the two air-to-air missiles Firestreak and Red Top, and the limited Blue Steel in active deployment to show for a vast misdirection of energy and money over the twenty years since the first V2 landed at Chiswick barely five miles from Whitehall'. *The Blunted Sword*, Hutchinson, London, 1964, pp.220-1.
6. In constant 1986 dollars. In that year the total defence bill was approximately $6500 million. Only in '50-51, '55-56 and '56-57 did joint project expenditure by Australia exceed in present values $116 million, which was the estimated budget for the Defence Science and Technology Organisation in 1986-87. Between 1947 and 1956, under the Dalton Formula, Australia alone paid for work in Australia.
7. In constant 1986 dollars. Britain began to contribute to the joint project expenses in Australia in the financial year 1956-57, under the Erroll Agreement.
8. WRE Joint Project Assessment Papers, March 1967. Paper No 1.
9. Ibid, pp.2-3.
10. Joint Committee on Foreign Affairs and Defence, *Disarmament and Arms Control in the Nuclear Age*, AGPS, Canberra, 1986, p.669.
11. Apart from the two serious accidents at the Range described elsewhere and several flying fatalities (not during trials) a WRE employee at Salisbury, Jillian Dare, was killed and several others injured when a mixture of HTP and methylated spirits exploded during a fire-fighting demonstration on 22 March 1960.
12. Paul Dibb, Review *of Australia's Defence Capabilities. Report to the Minister for Defence* . . . AGPS, Canberra, 1986.

Appendix: *The History of the Joint Project History*

by Jim Frost (*Defence Science and Technology Organisation, Department of Defence, Adelaide*)[1]

Complex commissioned histories often take far longer to write than the authors or sponsors ever expected, and so it was with the present book. From its inception thirteen years passed before the manuscript was finished and cleared for publication. Not all of those years were devoted to research and writing. There were false starts, inactive periods and changes of direction. Seven and a half years passed before the task was placed on a proper basis and work begun in earnest. My main reason for writing this appendix is to supplement the author's preface by outlining these various phases, most of which took place before his contract began. I also have the thought that other organisations contemplating a similar publication can perhaps learn something from our experience; it may help them to avoid some of the problems we faced.

It was in October 1975, just after the UK and Australia had negotiated an agreement to run down the joint project and to terminate it in 1980, that Alan Sharpe, a senior executive of the Department of Defence in Canberra, proposed that a history of the whole enterprise should be written. He considered the task important enough to warrant the full-time attention of one person. WRE Director Don Woods supported the proposal but thought that it would be difficult to find a person with the right blend of qualities: someone who had a flair for writing, who was prepared to wade through an immense volume of records, who had enough free time, and who had long experience in joint project work. Nobody could be found to match this probably unattainable combination, and consequently it was decided to limit the first phase to a preliminary gathering of data.

This was itself a monumental task. The sheer bulk of available records was daunting. How was a selection to be made, when so little thought had yet been given to the purpose and content of the History? In retrospect we see that this was the critical question which should have been clarified at the outset. As it was, working to no established principles, the man selected spent most of his time gathering a large mass of publications, files and minutes of meetings and making copious notes. A review of progress twelve months later produced a negative report and this first phase was abandoned. No doubt too much was expected.

The project now lay quiescent for some sixteen months, to be revived in August 1978 by Copas Montgomery, superintendent of the joint project component at Salisbury. This time, some more fundamental questions were asked: why should the History be attempted at all, for whom was it being written and how? Some answers were found to these questions, although they quickly started to look unsatisfactory. And the manpower to be applied to the job was still minimal. No departmental staff were to be assigned full-time to it. Writing it was to be a cooperative in-house venture, relying very much on those with relevant experience who were willing and able to devote part of their working or private time to it.

In November 1978 Montgomery set up a part-time committee of five under my chairmanship: this was my first active contact with the History. The committee's job was to co-ordinate the work, edit contributions as they came forward and later to arrange publication, which at that stage was to be done internally. Thus began the second phase of the work. Composed as it was of five people busy with higher priority tasks, our committee did not meet very often, and over the year of its life we did little more than organise an appeal for voluntary contributors and prepare a tentative outline of the contents.

Faced once again with disappointing progress, Montgomery decided that more concentrated effort was essential. He now replaced the committee with a small fulltime team. Because of the run-down, staff with a long background in the joint project were available; he selected two men and they started in November 1979. The new team began helping him to revise the contents, assess the response to the appeal for voluntary contributions, and draw up a plan for drafting chapters. The team then turned its attention to gathering more data. Meanwhile, Montgomery had secured the support of the UK Ministry of Defence through their Canberra representative at the time, Tom Pearson. Although it was recognised that most of the action would be in Australia, the Ministry agreed to help by seeking contributions, locating records and arranging clearance of the final text.[2]

I took over as team leader and manager of the project when Montgomery retired early in 1981. I made a progress review and tried to assess the likely completion date by setting up a simple model based on assumed rates of production of draft material. This took more time than it was worth because most of the assumptions could be little better than guesswork; none of us had any experience in journalism or authorial tasks.

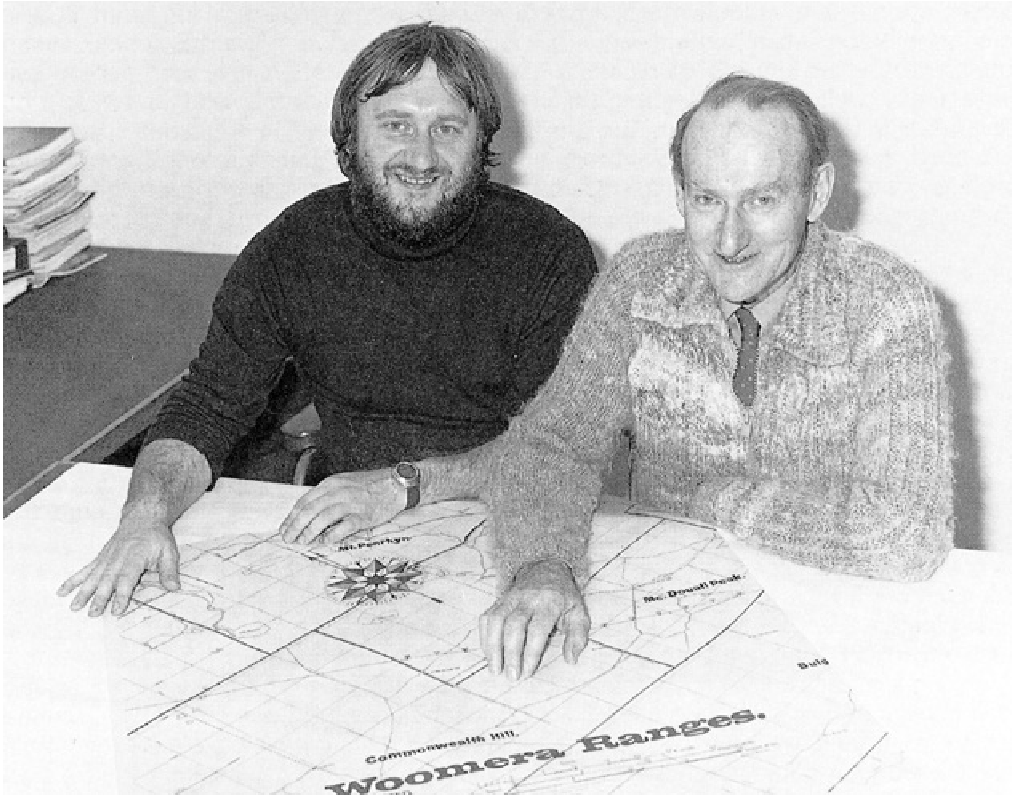
Despite frequent reminders, adequate written contributions were never forthcoming. Securing oral recollections was not difficult, as few people declined the opportunity to reminisce into a microphone. But conducting interviews and transcribing and editing the results was an extremely time-consuming process; a process which in the end might yield only a sentence or two of text from an interview. Clearly our small team would itself have to undertake most of the research, drafting and editing. How long would it take to finish the job? After two years the team had done a good deal in planning the structure and approach, gathering and sorting documents and other data, consulting newspaper references and compiling information folders. Even so, very little had actually been written; little more than my first draft of Chapter 1. Further, the other team member was due to retire shortly, and in any case neither of us claimed to have the flair for writing prose that the average reader would want to go on reading, and this was the most critical defect in the whole task.

In December 1981 I was asked to investigate using a professional writer under contract, as had been proposed by Woods early in 1976 but dismissed because of the cost. After examining various options, I concluded that adding such a writer to the team would not only give a superior product but would save both time and money. It was really the only way to finish the task within a reasonable time. My recommendation was accepted, and after advertising and interviews a contract was signed in April 1983 with the selected writer, Dr Peter Morton. Nevertheless the earlier concept of the history as a co-operative venture was not abandoned. Thus for about half the chapters the writer made full use of draft material written by others although edited by him, as he has indicated in the Acknowledgments, while many people contributed valuable comments on draft material sent to them, both in UK and Australia. Further, the departmental team assisted with research and drafting work, and was responsible for illustrations and overall task management.

In this fourth phase of the task, in which the writer and the departmental team were closely integrated, it was soon evident that we were on the right track after three unsuccessful tries. Our author was quickly immersed in research and drafting, and in the first ten months' work the 15 000 words of draft grew to 140 000, and eventually, after nearly four years of full time effort, the text had been written (but editing, clearance and preparing illustrations were to take almost another year of effort, although on a much reduced scale). It is true that arranging the contract and selecting a writer had diverted effort for nearly sixteen months, but it was effort very well spent.

During this phase a small but very useful contract was placed on Redpath Technical Services, one of the surviving guided weapons contractors in the Salisbury area, which led to our fortunate association with Ken Smith. Four of the chapters are basically his and his enthusiastic efforts far exceeded the bounds of the contract.

Looking back over the gestation and birth of the history, I can clearly see we made mistakes that with hindsight we might have avoided, giving us a smoother and shorter ride. This leads me to offer advice to others contemplating a similar venture. Perhaps it is wrong to generalise too far from our experience—we had a few special problems such as our necessary security clearance. Nevertheless I consider that any organisation should at least ask itself the following deceptively simple questions before embarking on a history:-



Jim Frost (*right*), manager of the task of preparing this history, with author Peter Morton.

Why do we want to write it? There are all sorts of sound reasons for writing history, but the ones that signify most to you should be considered, agreed and recorded, and perhaps weighted or qualified.

For whom is it to be written? This question is tied to the previous one. Thus if your history is being written to influence public attitudes or as an accounting to the public, then its content and style must appeal to the layman. If it is intended as a statement of record, then style, presentation and readability are less important than thorough research and an elaborate reference apparatus. Of course the history may well aim at both the layman and the historian, as does ours, in which case the question of balance should be constantly in view.

What is to be written? Is there a clear concept of what the final product should be like? Are those in charge of the project agreed on this? Consider not just the content, length, illustrations and so on, but the approach. Is it to be scholarly, entertaining, factual or a blend? Is it to pass judgment on past decisions and if so will the writer be free to state views contrary to the official line of the organisation? The clearance or 'censorship' issue should be faced squarely.

Can it be written? Is there adequate documentation? What shape are the primary sources in? Are there knowledgeable people still alive whose memories can be tapped to supplement the documents? Are the real likely costs understood and accepted?

Given that there are sound reasons for writing the history, that it can be written and so on, one must now decide whether it is really worth undertaking, remembering that it will inevitably take longer, cost more and need more determination than when first assessed. If the history is unlikely to become a firm commitment, strong enough to survive reasonable future setbacks, then it is better not attempted.

Who is to write it? The question of choosing the right author should be given special attention, because a wrong choice here will certainly wreck the task, perhaps after considerable effort has been put into it. One should avoid getting heavily involved in research before the writer is at work. There is no reason why sources of information should not be gathered at the outset, but research without the writer's guidance can easily become an end in itself, wasting time in seeking the wrong data while giving an illusion of progress.

If you are planning a semi-popular work, beware of the fable that any competent specialist or administrator, experienced in writing technical or other papers and submissions, can write lively and readable narrative likely to appeal to an intelligent layman unused to technical jargon or officialese. A few such people can write really well, even brilliantly: Nevil

Shute was an aeronautical engineer who became a masterly storyteller. But the chances are against it. Remember that you will need an individual who is not only a skilled author but is also self-motivated, used to working alone, and has the discipline to carry through the task thoroughly and diligently.

Unless you are very lucky or your ambitions are modest, you will have to look for such a writer outside your own organisation. The ability to produce *to order* accurate yet appealing manuscript from indifferent materials, such as voluminous files and dry technical literature, is a rare skill. Like any such skill it needs innate ability, education and experience, and it has a price. Decide what quality of job you want done, seek expert advice from those who know the writing profession, and set your budget accordingly. As a guide, you are unlikely to be paying less than you would for a skilled and experienced professional in other fields.

An argument often used is that only someone inside the organisation, who has lived with the venture to be recorded, can possibly write its history. Certainly such people are invaluable in the research phase and in contributing written drafts or oral reminiscences. But using an outsider has advantages on other points. He or she is more likely to see the wood rather than the trees, more likely to make disinterested unemotional judgments, and less likely to be over-influenced by the rules and traditional views that every organisation generates.

Do not, of course, go to the other extreme of engaging an outside writer and then leaving him or her to do all the work, including ferreting out documents, finding people to interview, even managing the task. An outsider will need considerable management support and direct help with research, preferably full-time, to make best use of his or her talents.

Selecting the writer is very important, and should be done by seeking expert advice at every stage. Advertise widely, taking care to outline the proposal and the part to be played by the writer (best done by preparing notes to be sent to inquirers rather than attempting to cover it all in a short advertisement). Decide what attributes you are looking for in the writer, and make sure you have somebody on the interview panel competent to judge such attributes in interviewees. Make sure the contract covers all the vital matters, e.g. what is expected of the writer, period, payment, access, facilities to be provided and break clauses etc. Many of these will have to be negotiated before signing, perhaps before making the final selection. Do not simply select the lowest price or even the shortest timescale—demonstrated writing ability should be paramount.

Like any task you will need to set deadlines and to measure progress from time to time, but do not be too ambitious, as writing by its nature proceeds in fits and starts, and does not lend itself to firm forecasting of end dates.

If after considering all this advice you are still keen to go ahead, then I wish you well in your very worthwhile endeavours, and hope that you find it as absorbing and satisfying as I found my part in creating *Fire Across the Desert*.

Notes and Sources

1. This appendix is a revised and updated version of J. M. R. Frost 1985. 'History of a History: the Woomera Story'. *Second National Conference on Engineering Heritage*, Melbourne, 20-22 May 1985. The Institution of Engineers, Australia. Preprints of Papers, pp. 96-99. (National Conference Publication No. 85/3).
2. The UK Defence Committee issued a Defence Council Instruction in 1979 and again in 1980, authorising all Ministry staff associated with the joint project to contribute. In the meantime Pearson had retired after returning to UK, but for a while he was retained part time by the Ministry to co-ordinate the UK share in the history, and he contributed much of the material himself. In the later stages he continued as an unpaid consultant, and thus he remained for some years the sheet anchor of the UK contribution.

Select Bibliography

This bibliography makes no attempt to be a comprehensive guide to published materials on topics covered in the History. That would be a daunting task indeed. Rather it is a list of openly available sources which the reader may find useful to fill in the background of post-war British and Australian defence policy and practice, and the technological history of rocket and missile engineering.

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