TIROS Preflight Testing and Postlaunch Evaluation

Edwin A. Goldberg*
Radio Corporation of America, Princeton, N. J.

Eight TIROS satellites have been launched into orbit and have successfully performed the mission for which they were intended. The attainment of the scientific and engineering objectives for these spacecraft is, in large measure, the result of a comprehensive testing and evaluation program. The test phases for flight-qualified payloads include acceptance, hangar, on-stand precountdown and countdown, and postlaunch evaluation. Several special test fixtures were designed explicitly for this test program. In evaluating the performance of TIROS I, a "magnetic-dipole" effect was discovered which caused precession of the satellite's spin axis. This effect has now been usefully applied for active attitude control on several TIROS satellites and also for the Relay satellites.

1. Introduction

EIGHT TIROS meteorological satellites have been launched, and each one has successfully performed its mission of providing cloud-cover pictures suitable for weather analysis by trained meteorologists. The results of these studies have been reported in several papers.[1,2] Three of the satellites also carried NASA/Goddard Space Flight Center (GSFC) infrared instrumentation for measuring heat emanating from the earth and its atmosphere. The success of each mission hinged on the satisfactory performance of each major component of the over-all system complex. These components include the launch-vehicle system, the satellite-tracking network, the satellite, and the satellite-system ground complex. This paper will highlight the nature of the various phases of testing of the satellites themselves. The test program was planned to uncover weaknesses in designs, workmanship, and materials which might adversely affect the satellite performance in the launch and space environments. Performance and environmental testing of the major components of each subsystem were conducted prior to the assembly of these components into a complete satellite for both prototype units and flight units. The major subsystems and components carried aboard TIROS I through VII are listed in Table 1.†

Some special specific-performance tests were conducted to evaluate the capability of the design to meet certain performance specifications. Some of these tests, because of their nature, were performed on only one satellite and will be discussed briefly under special performance tests.

Each complete prototype and flight-model satellite was subjected to calibration, functional, and environmental tests. Flight models were shipped to Cape Kennedy only after having successfully completed all of the forementioned tests.

Further tests conducted at the Cape included "hangar" checks, and "on-pad" checks. After launch, a series of orbital-evaluation tests were conducted. The nature of each of these phases of tests will be covered in the appropriate section of this paper.

Presented as Preprint 63106 at the AIAA Space Flight Testing Conference, Cocoa Beach, Fla., March 18–20, 1963; revision received December 20, 1963.

* Manager, Spacecraft Design and Test, Astro-Electronics Division, Defense Electronic Products, Princeton, N. J. Member AIAA.

† TIROS VIII was launched into orbit on December 21, 1963 (since this text was first written) and is still performing satisfactorily. To date, it has transmitted approximately 9000 pictures from its conventional TIROS camera and approximately 1200 pictures from the Automatic Picture Taking (APT) camera.

2. Specific Performance Tests

To evaluate the satellites completely, as required by the specifications, a series of special specific-performance tests were set up. These tests were separated from the usual calibration and environmental tests and were not necessarily repeated on complete satellites because of the nature of the tests. This special series confirmed the performance or characteristics of the antenna (pattern), TV cameras (light-response), solar cells and batteries, structure (loading), despin mechanism, magnetic-field drag, and thermal behavior.

Antenna-Pattern Measurements

Special facilities were constructed to permit the taking of highly accurate field-strength measurements in the determination of antenna patterns. Measurements were made using both reduced-scale and full-scale models of the satellite. The measurements with the actual satellite configuration were made with the spacecraft mounted on a tall wooden structure in an attempt to simulate free-space conditions. It was determined in this manner that the critical transmitting antenna pattern was isotropic within ± 3 db at 236 Mc and within +4 and −8 db at 108 Mc (or, in the case of TIROS IV, V, and VI, within +4 and −8 db at 136 Mc).

TV-Camera Response Tests

The TV-camera response tests included checking the TV subsystems' spectral response, as well as its response to vary-

Table 1 Major subsystems carried by TIROS satellites I–VII

	Flight number						
Subsystem	1	2	3	4	5	6	7
TV camera subsystem							
Wide-angle	1	1	2	1	1	1	2
Narrow-angle	1	1	0	0	0	0	0
Medium-angle	0	0	0	1	1	1	0
Command and control subsystem	2	2	2	2	2	2	1
Telemetry and beacon subsystem	2	2	2	2	2	2	2
Radiometer (ir) subsystem							
Omnidirectional	0	0	1	1	1[a]	0	1
5-Channel, scanning	0	1	1	1	1[a]	0	1
2-Channel, wide-field	0	1	1	1	1[a]	0	0
Spin-rate control	1	1	1	1	1	1	1
Attitude sensor	1	1	1	1	1	1	1
Orientation sensor	1	1	1	1	1	1	1
Magnetic steering	0	1	1	1	1	1	1

[a] Although these units were physically on board TIROS V, they were disconnected electrically before launch.

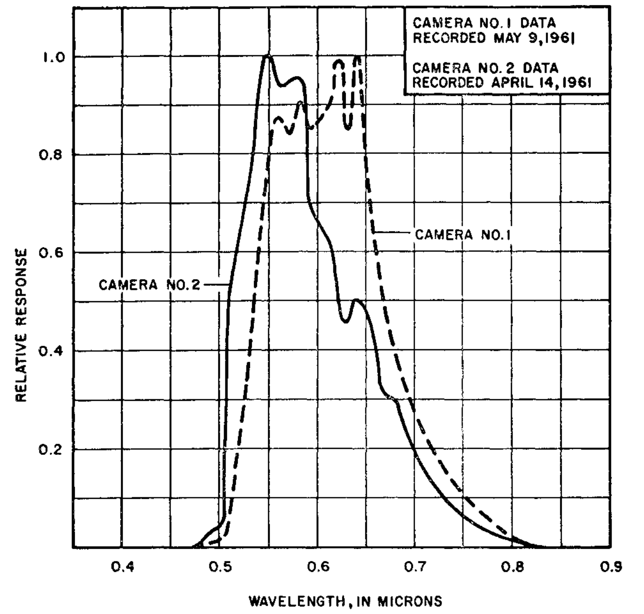

Fig. 1 Spectral response of TIROS II TV cameras.

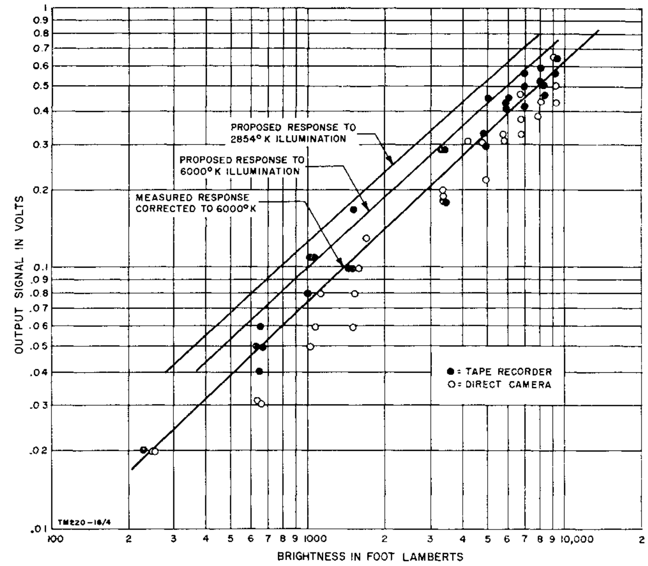

Fig. 2 Brightness response of a TIROS II camera.

ing scene brightness. The spectral-response checks were made to determine the effects of the nonvisible light spectrum on the vidicon output and to determine the differences in the spectral response of the individual vidicons. The brightness-response checks were made to insure that the threshold and saturation points of each vidicon were within the required limits.

The vidicon camera was tested for spectral response after the qualification tests were completed but prior to its mounting on the satellite baseplate. The tests were made using a Perkin-Elmer 112-V spectrometer and a monochrometer. The signal from the camera itself was amplified in the video circuitry and measured as a video voltage on an oscilloscope. The spectral responses of the two TV-camera systems installed in the TIROS II satellite showed that the "nonvisible" light had little effect in the output from the TV subsystem. Plots of the cameras' spectral responses are shown in Fig. 1.

The response of the TV cameras to varying scene brightness was checked using a brightness source consisting primarily of a light-box with three separately controlled illumination sources operated at a constant 2854°K. The resultant data were converted to the value that would have resulted if a 6000°K light source had been used. The response of the cameras to varying scene brightness is shown in Fig. 2.

Absolute-brightness measurements of the brightness source were made with a Spectra model SB-$\frac{1}{2}$° brightness meter. The brightness-response tests showed that the cameras provided a discernible output for an illumination of 500 ft-L, whereas more than 13,000 ft-L were required to saturate the cameras.

Solar-Cell and Battery Tests

Several special test devices were developed for use in evaluating and selecting the solar cells to be used on the flight-model satellites. An indoor unit was designed for solar-cell evaluation under controlled-lighting conditions; an outdoor fixture was used for direct-sunlight observations of small numbers of cells; a second outdoor unit was built to evaluate and test the completed satellite units; and a production-type unit was built for rapid selection of individual solar cells. Original evaluation of various types of solar cells was carried out with the use of the two first-mentioned units. Each of these units provides a separate and precisely controllable test to evaluate the basic solar-cell unit. The use of large quantities of these cells necessitated a means of quick and accurate quality control and final assembly checkout. A "mass" solar-cell tester developed by the Radio Corporation of America (RCA) provided the quality-control checks of thousands of cells per day with variable conditions to simulate a standard June 21 solar illumination, from sea level to orbital conditions. The final assembly checkout was done by shading various sections of the completed units in the sunlight and using pyroheliometer measurements with voltage and current readings as a final check of power-output capabilities.

Structural-Loading Tests

The structural-loading tests were made with a unique test fixture designed by RCA. A view of a satellite structure under test in this fixture is shown in Fig. 3. This facility allowed individual tests to be carried out on either the baseplate alone or on the complete satellite structure. Loading forces up to 40 g (which is 80% of the design limit) were used, and significant stress and deflection measurements were made to prove the design. Mass-distribution plates

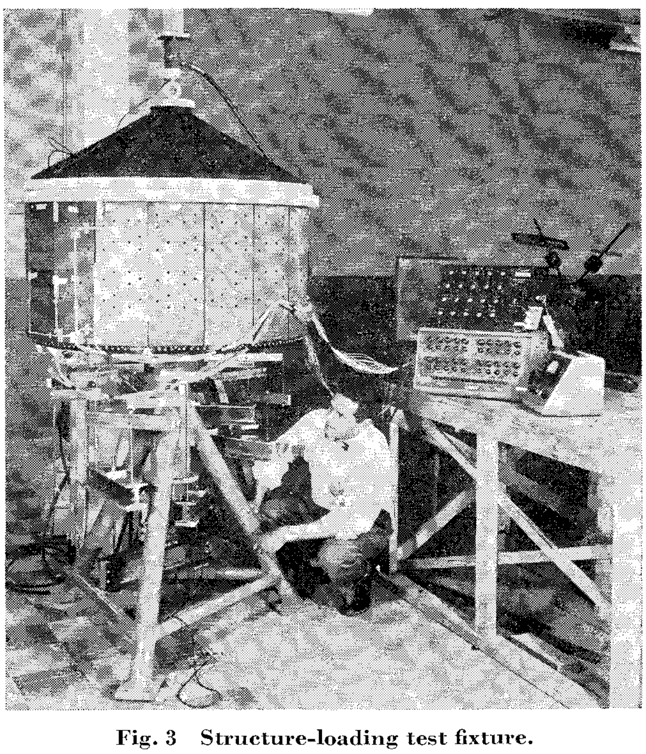

Fig. 3 Structure-loading test fixture.

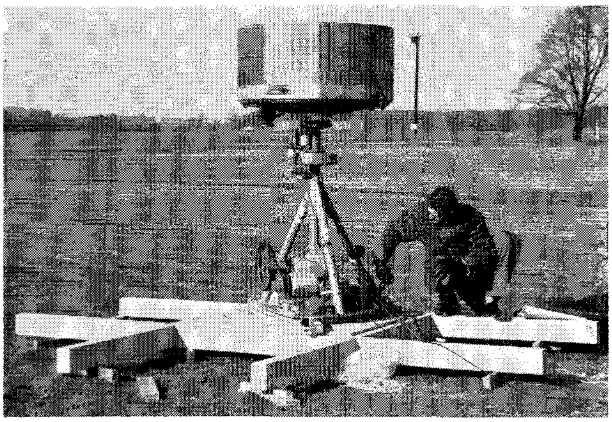

Fig. 4 Satellite-despin test fixture.

were used to load the baseplate, a pressure bag fabricated of Mylar provided even distribution of the load applied to the top, and additional loading was applied to the structure by a hydraulic jack. Forces up to 40 *g* were applied.

Despin Tests

The despin mechanism (a Yo-Yo type of device) was designed to reduce the satellite's rotational speed from a nominal rate of 120 rpm, acquired during launch, to the operating rate of approximately 9–12 rpm. The elements of the system were designed and tested with a dummy vehicle. After the elements were installed in the actual satellites, special tests were required to test the functioning of the system. The final spindown, as recorded on the ground, would not be the same as in space because of the effect of the air drag on the weights, but the results could be extrapolated.

The satellite was mounted outdoors on a special fixture designed to spin it at launch speeds. By a command signal to the satellite, the squibs were fired, and the despin weights were released. A photograph of this test fixture is shown in Fig. 4. After 30 tests were performed on a simulation model, four tests were conducted on the test-model satellites. All tests showed successful operation with inthe limitations of the atmospheric environment. Actual space conditions could not be duplicated for these tests, but the actual functioning of the despin device in space proved that the tests given were adequate.

Magnetic Field Tests

To evaluate properly the effect of the earth's magnetic field on the satellite, a special test fixture was constructed with field coils capable of producing up to 200 gauss and with hydrostatic bearings for minimum friction at the speeds of interest.

Reproducible data were taken from tests made on a complete satellite; and extrapolations made from this data, together with calculations, provided necessary information on the effects of the earth's field on the spin rate.

Thermal Tests

The accuracy of the thermal-balance condition calculated for the satellite was proved by placing the entire payload in a 48-in. vacuum-thermal chamber under controlled conditions. A specially designed heat source was placed near the top of the satellite and heated to 278°F, to simulate heat from the sun. The walls of the environmental facility were cooled to −78°F, the lowest possible with the large heat load, to simulate the temperature of outer space. Under vacuum conditions, with the satellite operating, stabilized temperatures were measured at 22 locations. (These tests were initially performed in 1959, when the state of the art of space simulation was in its infancy.)

3. Satellite Environmental Testing

Satellites are subjected to a wide range of environmental conditions. It is possible to control the environment between rather close limits of temperature, humidity, shock, etc. prior to launch. During launch, however, the satellite

Table 2 Environmental test specification summary for TIROS satellite

Test	Axis	Specification: TIROS prototype	Specification: TIROS flight
	Subsystems		
Vibration	Thrust	25 *g* rms, 2 min	10 *g* rms, 2 min
20–2000 cps white noise	Each lateral	20 *g* rms, 2 min	10 *g* rms, 2 min
Shock	Thrust	15 *g*: 5 shocks, each direction	No requirement
Pulse form: ½ sine wave of 11 ± 1 msec duration	Each lateral	10 *g*: 2 shocks, each direction	No requirement
Acceleration	Thrust	50 *g*, 5 min	No requirement
Thermal-vacuum	Each lateral	20 *g*, 2 min	No requirement
In 5×10^{-5} mm Hg environment	...	60°C, 12 hr	55°C, 12 hr
	...	25°C, 12 hr	25°C, 12 hr
	...	−10°C, 12 hr	−10°C, 12 hr
	Spacecraft		
Vibration	Thrust	21 *g* rms, 2 min	7 *g* rms, 2 min
20–2000 cps white noise	Each lateral	14 *g* rms, 2 min	7 *g* rms, 2 min
Resonant burning			
550–650 cps: sine wave	Thrust	50 *g*, 1 min	25 *g*, ½ min[a]
Acceleration	Thrust	35 *g*, 3 min	None
Spin	Thrust	150 rpm, 5 min	150 rpm, 5 min
Thermal-vacuum			
In 5×10^{-5} mm Hg environment	...	50°C, 5 days	50°C, 3 days
	...	60°C, ½ day	...
	...	25°C, ½ day	25°C, ½ day
	...	0°C, 5 days	0°C, 5 days
	...	−10°C, ½ day	...

[a] Limited to one spacecraft.

is subjected to static accelerations of several g's, severe mechanical vibration, and rather rapid changes in ambient pressure and temperature. Once in orbit, the environment is one of essentially zero, externally applied mechanical forces; extreme vacuum; and variable radiant-energy conditions. An environmental test program was planned to subject the satellite to artificial environments designed to demonstrate the capability of survival in this environment and to operate as intended. Two levels of environmental testing were employed. Prototype units were tested under more severe vibration levels than flight units to determine if the design was adequate to meet vibration. Vacuum-thermal testing was performed on both prototype and flight units. Static acceleration tests were performed on only one prototype. No combined-environment environmental testing was performed on the TIROS program. The environmental test program was planned by an environmental test committee chaired by the NASA-TIROS spacecraft systems manager. The plan was laid out in considerable detail, and the committee had the responsibility of evaluating environmental test results to determine if test specifications had been met. All changes in the test program required approval in advance by the committee and concurrence by the NASA project manager.

Vibration Testing

Prototype vibration testing was conducted on one prototype unit at a level of random vibration (ranging between 20 and 2000 cps) equivalent to three times the level expected to be encountered during the launching operations; for sinusoidal vibration, inputs were applied from 550 to 650 cps at 50-g peak (this relating to the vibration expected to be encountered because of resonance burning of the third-stage rocket). Flight units were tested at random vibration levels expected to be achieved in flight. A summary of the vibration test conditions is given in Table 2.

During the initial prototype vibration test on a TIROS I test-model satellite (no. T-2), fractures occurred in the sheet-metal chassis of several units. These fractures, which showed up after the random noise test at 21 g rms from 20 to 2000 cps, were observed in the bases of several units that had high ratio of height-to-base mounting area. To clarify further the cause of these failures, a survey was conducted to determine the "Q" at the upper end of all units in the vehicle when the baseplate was driven along the thrust axis.

In order to correct the observed failures, a two-phase redesign was incorporated. First, the individual chassis in question were replaced with chassis strengthened by adding doubler plates to their bases and stiffening gussets between the base and vertical members. Second, after these strengthened units were remounted on the baseplate, "bridging" brackets were added to couple the tops of adjacent units to provide mutual stiffening for these units and reduce their Q, as well as to insure against detrimental effects on the batteries owing to excessive vibration. After this two-phase redesign had been incorporated, the T-2 satellite was subjected to a random-noise test of 21 g rms from 20 to 2000 cps. After this test, a careful inspection of the reworked chassis failed to reveal any sign of fracture. The spacecraft had then passed its third-level vibration tests.

Thermal-Vacuum Testing

Summary specifications for the thermal-vacuum testing of the prototype and flight-model satellites are included in Table 2. These tests were designed to subject the satellite to high- and low-temperature extremes, somewhat in excess of those values expected to be encountered in orbit, for a considerable period of time. The pressure in the vacuum-chamber in which the tests were conducted was maintained at 5×10^{-5} torr, which is considerably below the pressure at which heat transfer through convection becomes negligible

Table 3 Components tested during thermal-vacuum tests

Command receiver	Clock (timing and playback)
TV transmitter	Attitude control
TV camera chain	Spinup and delay timer
Infrared (Interrogation)	

(i.e., 1×10^{-4} torr). During vacuum thermal-testing of the prototype, only one major problem occurred which required a redesign. During the test, a high charging rate produced internal gas pressure that bulged the battery cases. This, in turn, ruptured the battery heat sink, causing eventual internal failure of some cells because of excessive heating. As a result, current regulators were added to control the charging rates, and the battery case was designed to prevent its bulging from destroying the heat sink. Several deficiencies in components and workmanship were also discovered on flight units during this phase of testing.

Parameters of various components, listed in Table 3, were periodically measured during the thermal-vacuum tests. The specific measurements made on the clock are given in Table 4.

4. Alignment and Calibration

Upon successful completion of all environmental-acceptance tests, each flight unit was given a thorough quality-control inspection to check the tightness of each screw and nut, the conditions of electrical connections, and to look for the presence of dust, dirt, or other unwanted foreign materials. This inspection was followed by a series of final alignment and calibration checks. A test fixture used for calibration of the TV cameras of TIROS I and II is shown in Fig. 5.

Each TV camera was checked for sensitivity, focus, distortion, and alignment relative to the satellite reference system (which consists of the spin axis and the "North" or "zero" reference).

The alignment of the sun-angle reference system and the horizon scanner were checked. A final dynamic balancing was performed. The maximum unbalance allowed was 6 oz-in. A measurement of the magnetic moment under the various modes of operation was made. Permanent magnetics were installed to provide a zero residual magnetic moment for the operating condition when the satellite is not being interrogated. These calibration measurements were made on units that incorporated the magnetic "steering" coil (that is, TIROS II and subsequent units). TIROS II, III, and IV incorporated the NASA/GSFC infrared experiments. These were calibrated with respect to sensitivity, field-to-view, and physical alignment. Flight units were shipped to the launch site only after these final checks were accomplished.

5. Launch-Site Tests

The TIROS I prototype unit was used, at the launch site, for training purposes, including dry-run tests. Flight units,

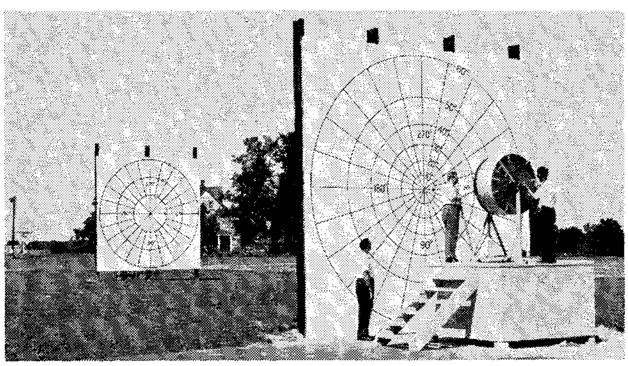

Fig. 5 Outdoor test complex for TV-camera calibration.

Table 4 Operating parameters of satellite clock measured during thermal-vacuum tests

Test 4
Clock timing and playback
A. Program for playback 1 and playback 2; set both clocks and start clocks
1. Clock 1 set
2. Clock 2 set
3. Elapsed time between start and alarm of clock 1
4. Elapsed time between start and alarm of clock 2
5. Use collimated light target during record
B. Program playback 1
1. Horizontal sync frequency, cps
2. Vertical frame time, sec
3. Playback running time, sec
4. Record subcarrier deviation, kc
During playback of recorded pictures
5. Take "A" scope Polaroid picture without video
6. Take "A" scope Polaroid picture with video
7. Take Polaroid picture of monitor display
8. Take 35-mm pictures of playback
C. Program playback 2
1. Horizontal sync frequency, cps
2. Vertical frame time, sec
3. Playback running time, sec
4. Record subcarrier deviation, kc
During playback of recorded pictures
5. Take "A" scope Polaroid picture without video
6. Take "A" scope Polaroid picture with video
7. Take Polaroid picture of monitor display
8. Take 35-mm pictures of playback

upon their arrival, received electrical and mechanical inspections. In fact, each satellite was given rather thorough electrical tests to determine if any performance changes had occurred during shipment from RCA. They then were mated with their third-stage rockets, and the assemblies were checked for mechanical alignment and proper clearances. A crew engaged in a clearance check is shown in Fig. 6. When a particular satellite and third-stage rocket assembly was selected for a flight, it was transferred to the launch complex and mounted on the second-stage rocket. An air-conditioned tent installed on the gantry protected the satellite and third stage from adverse weather until the time of launch.

Prelaunch Tests

Satellite checkout equipment

For satellite testing at the launch site, a special facility was designed by RCA. This equipment was essentially a manually programed ground station of reduced capability which permitted the conducting of a series of tests at the Atlantic Missile Range. The main intent of these tests was to check operability of the various satellite functions, rather than to give complete quantitative tests.

The equipment was housed in a laboratory-type van and consisted of the required antennas, transmitters, receivers, video-processing equipment, telemetry-processing equipment, and the necessary units for control of the satellite functions. Additional units were installed to permit manual operation of a TLM-18 antenna, so that the van equipment could be converted to a backup operational ground station.

Launch-site test program

The satellite test program at Cape Kennedy consisted of a daily functional check of operation of each of the payloads with the Go, No-Go equipment. When the selected satellite was mounted on the missile and readied for launch, a careful visual check and an operational check were performed each day. Additional interference checks were made as required in the countdown manual during rf-systems day and all-systems day.

Go, No-Go tests made while the payload was on the missile were conducted by three separate crews: one crew in the Go, No-Go van, a second crew on the gantry, and a third (one man) monitoring the blockhouse-control panel. The personnel in the Go, No-Go van controlled the satellite and checked the resulting data. The gantry crew operated the auxiliary test equipment to provide the required target sources for the sensors. The man in the blockhouse monitored and recorded battery conditions during test periods. All telemetry data were compared to a master (i.e., a paper-chart overlay) during each test. NASA/GSFC representatives were present in the Go, No-Go van to monitor all payload checks.

Takeoff Day Prelaunch Operations for Tiros I

Takeoff day began at 2000 EST on March 31, 1960. The payload checks were made at T-505 min (2000 EST), at T−195 min, and at T−95 min.

The payload check was started at 2030 EST and progressed satisfactorily until the operation of the remote-timing function of the satellite was checked. Timing errors were found and ascribed to unauthorized jamming by a transmitter in the immediate area which had a frequency very near the command frequency. No further problems were found after the extra transmitter was taken off the air. The payload check was completed satisfactorily at 2124 EST. During the next few hours, the payload was given a very thorough visual examination, and all extraneous material was removed. At the completion of this inspection, the flight fairings were installed, and the T−195 min checks were made (at 0245 EST, April 1) without incident. Following this, the gantry was removed. The last scheduled check was the T−95 check, and this was completed satisfactorily at 0345 EST. At approximately T−60 min, it was discovered that battery-charging leads exterior to the satellite were open, and battery conditions could not be monitored during the remaining countdown time. It was decided that, at T−10 min, a very short payload check would be made to get telemetered information

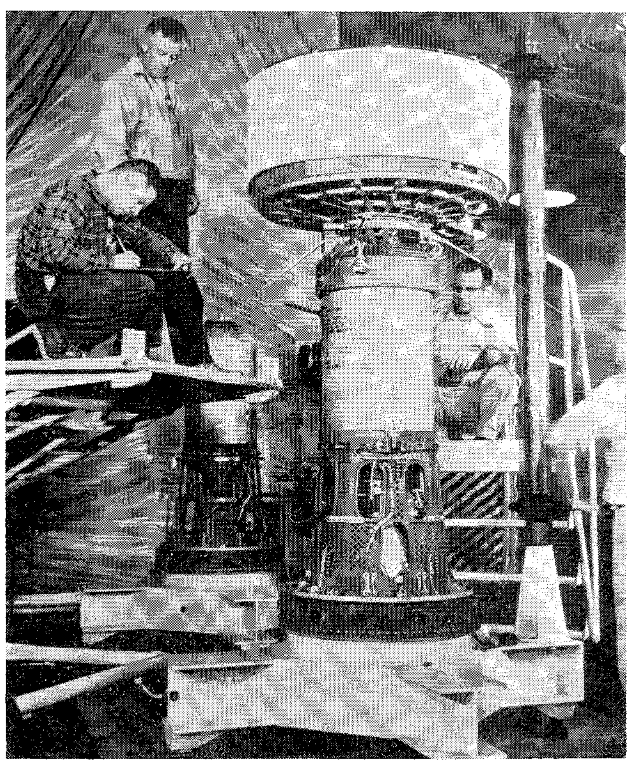

Fig. 6 Clearance check after satellite mating with third-stage rocket (at launch site).

on batteries. At 0535 EST this was done, and the batteries were shown to be in good condition. A 1-hr hold at T−2 min required that this condition be rechecked at 0631 EST. Everything was found to be satisfactory. The rocket and payload then were considered ready for launch.

6. Postlaunch Evaluation

TIROS I was purely an experimental satellite intended (from a meteorological viewpoint) to prove the feasibility of an orbiting cloud-observation station in space and to prove the feasibility of using cloud photographs for meteorological analysis and research. Although the equipment comprising the instrumentation was, by intent, restricted to state-of-the-art components, the deviations and redesigns necessary to adapt these to space requirements made the direct functioning of each component a matter of experimental interest as well.

The results obtained from TIROS I more than met expectations from the standpoint of picture quality, both for real time and for delayed transmissions. Data inherent in the pictures proved to be of considerable value to meteorologists; e.g., it gave them a view of broad weather patterns previously unobtainable.

The TIROS cloud-cover data correlated excellently with weather-map data generated by observations from normal weather observation stations. The feasibility of detecting cyclones and hurricanes in their formative stages and tracking them as they developed was effectively demonstrated with TIROS I. TIROS I was extremely successful in proving that TV observations of cloud-cover patterns from space above the atmosphere are of considerable value to meteorologists for weather analysis and research.

The TIROS satellite was designed to operate within certain temperature ranges while in orbit, and it was believed that this could be done without the use of active temperature-control devices.

Characteristics of the surface finishes were, therefore, quite critical. These finishes were carefully specified on the basis of certain physical measurements in the laboratory and extensive thermal-balance calculations. Telemetered data giving these satellite temperatures showed very close correlation with predicted temperatures. Figure 7 is a plot of such data. These results are an indication of the soundness of the theoretical and experimental methods used in the thermal design.

Orientation of the spin axis of TIROS I as a function of time, defined in terms of declination and right ascension angles in the astronomical-celestial-sphere coordinate system, deviated from the predicted values. Originally, it was assumed that some precession of the spin axis would be caused by differential-gravity forces, but the observed precession was greater than could be accounted for from this effect. Therefore, it was apparent that other forces were torquing the spin axis. It was postulated that these forces might be magnetic because of the interaction between the earth's magnetic field and a magnetic dipole moment existing in the satellite. A mathematical model verified the assumption of

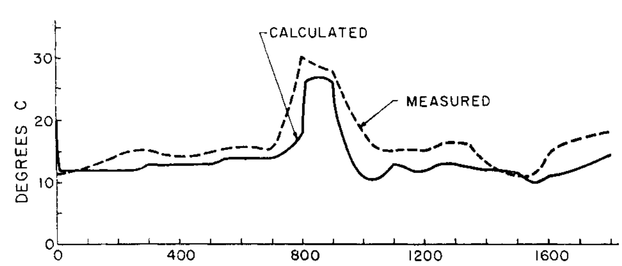

Fig. 7 Comparison of calculated and measured component temperatures on TIROS II satellite.

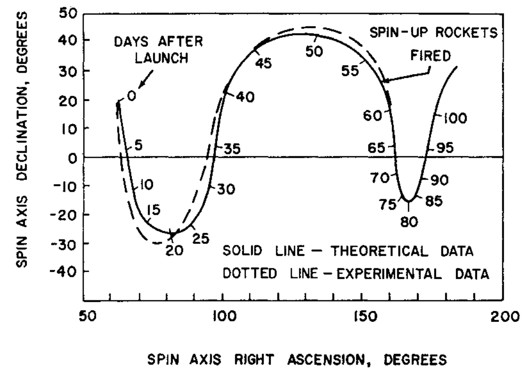

Fig. 8 Comparison of calculated and measured spin-axis precession of the TIROS I satellite.

a finite magnetic-dipole moment for the satellite; resultant predictions of spin-axis motion for a 2-month period turned out to be accurate. Once the cause of this motion was identified, it became possible to compute rather accurately the continuing precession of the spin axis. Figure 8 shows the type of correlation that exists between observations and calculations of precession when this effect is considered. All TIROS satellites, beginning with TIROS II, utilized this effect to reorient the spin axis on command from the ground. A coil, wound in a plane normal to the spin axis, was fitted around the satellite structure. Provision was made to program electric currents of different magnitude and polarity through the coil to provide a precalculated torquing of the satellite. To demonstrate the effectiveness of this device, TIROS II was programed to provide 14 consecutive days of camera-coverage of a single area, the Gulf of Saint Lawrence. Measurements of dipole moments are now made on each TIROS satellite, using measuring techniques, as illustrated in Fig. 9, as a part of the final calibration procedure. Additional experiments have been incorporated on several TIROS models.

The infrared heat-measuring subsystem was designed and produced by NASA/GSFC to measure heat radiation and reflected solar radiation from the earth and its environs in that portion of the electromagnetic spectrum ranging from the infrared to the ultraviolet. Provisions were included

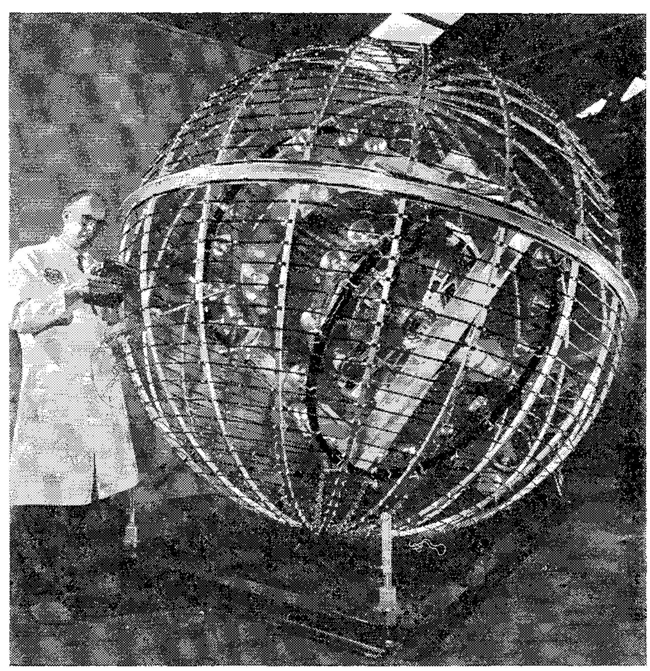

Fig. 9 TIROS satellite in test fixture designed to measure dipole moment.

Table 5 Comparison of first seven TIROS satellites

	Flight number						
	1	2	3	4	5	6	7
Launch date	April 1, 1960	November 23, 1960	July 12, 1961	February 8, 1962	June 19, 1962	September 18, 1962	June 19, 1963
Initial orbit							
Inclination	48.37°	48.49°	47.87°	48.29°	50.08°	58.27°	58.23°
Perigee, km	681	594	763	726	598	690	621
Apogee, km	759	755	792	827	965	707	649
Useful life, month	3	$12\frac{1}{2}$	$7\frac{1}{2}$	$5\frac{1}{2}$	11	13	$5\frac{1}{2}$[a]
No. of cloud pictures returned	23,000	37,000	36,000	32,500	58,200	66,500	31,000[a]

[a] Subtotal still operational as of November 1, 1963.

which allowed the system to record continuously the radiation data measured during an orbit and to play back and transmit the recorded data at an accelerated rate during a shorter period when commanded by an interrogation pulse from the ground station. Telemetry parameters also were recorded continuously, and those provided the necessary information on operating conditions. The environmental qualification and calibrations for this subsystem all were performed by NASA/GSFC, during subsystem as well as completely integrated payload tests. The same environmental specifications used for the TV portions of the satellite were applied to the qualification of the ir subsystem.

A comparison of the operational parameters and performance of the first seven TIROS satellites is given in Table 5. For TIROS V and VI, the TV-subsystem figures given are those that were applicable on February 1, 1963. TIROS V functioned until May 1963 and TIROS VI until October 1963.

7. Summary and Conclusions

Throughout the TIROS program, a combination of rigid performance requirements and environmental tests contributed greatly to the success of the several orbiting satellites. Performance tests were started early in the manufacture of each component and were combined and repeated up to the time of launch of the complete satellite. Environmental tests were extensive and were based on the following concepts.

The levels of mechanical testing for the prototype spacecraft were from two to three times as great as the levels expected during the launch phase. This margin of safety insured that the probability was high and that the flight units would satisfactorily survive. As a matter of record, there have been no failures during the boost phase of any one of the seven TIROS spacecrafts, which have been put into orbit by the Douglas Delta launch vehicles.

Another factor in the successful performance of the TIROS satellites is considered important: The group of NASA/GSFC and RCA technical personnel, which followed each satellite from TIROS I to VII during the course of its integration and environmental tests at RCA and the Atlantic Missile Range, has remained practically unchanged. These personnel became thoroughly familiar with all aspects of each satellite and could quickly assess all actions and reactions at any time. Satellites are not yet assembly-line items, and personal attention and understanding remain one of the ingredients of success.

References

[1] Sternberg, S. and Stroud, W. G., "TIROS I meteorological satellite," Astronautics **5** (June 1960).

[2] Sternberg, S. and Schnapf, A., "Performance and evaluation of satellites TIROS I and TIROS II," ARS **J. 31,** 1495–1505 (1961).