PLANNING MICROWAVE DEVICE R&D FOR DEFENSE

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ABSTRACT

The paper reviews the DOD planning process and presents the historical evolution of content and funding of the DOD electronic devices program since the late 1950's, with emphasis on microwave devices.

Introduction

In this talk we will try to give you some insights into the planning process in DOD, and illustrate with the development, current status, and prospects for electronic devices, particularly microwave devices.

The purpose of planning may be thought of as the generation of an equation balancing needs and opportunities against resources. Usually needs and opportunities are greater than resources, and planning entails selecting in such a way as to leave a sound, purposeful program.

Electronics Technologies

Before we can plan R&D, we must recognize and define the objectives of R&D, and the technologies with which those objectives are to be met. The overall objectives are referred to as the mission, examples of which on a national scale might be a stronger defense or Man on the Moon. To achieve these objectives we must develop functional technologies, such as transport and communication systems, or rockets and navigation. These functional technologies develop out of the mission needs and the indispensable basic technologies, of which electronic device technology and computer technology are two good examples. Finally, these basic technologies grow out of basic research, for which a need is perceived even when the final applications are not obvious.

The functional technologies in Defense Electronics may be summarized as follows:

- o Search
- o Guidance and Control
- o Communications
- o Command and Control
- o Electronic Warfare

The basic technologies in Defense Electronics may be stated as follows:

- o Electronic Devices
- o Digital Computer Technology
- o Electromagnetic Propagation
- o Electronic Materials

The top-down approach to planning R&D may be summarized as shown in Fig. 1. Notice that there is constant feedback once the Operational Requirements have been established. Planning R&D is a dynamic process, and its ultimate outputs are the Technical Thrusts.

Categories of R&D

In DOD jargon, you will hear talk about Programs 6.1 (Basic Research) thru 6.2 (Exploratory Development), 6.3 (Advanced Development), and so on. They

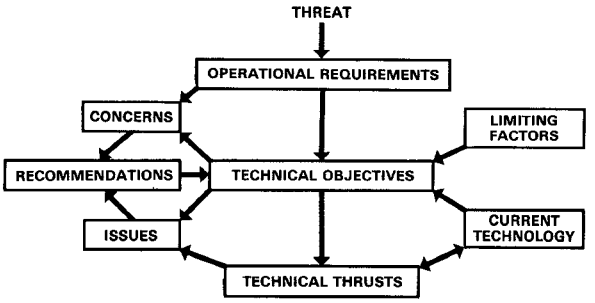

Fig. 1. Top-Down Approach to Planning R&D

progress from more basic (the lower numbers) to more applied (the larger numbers). The lower numbers 6.1, 6.2, and part of 6.3 are collectively known as the Technology Base, or as Science & Technology, and are controlled by a single office in DOD. See Fig. 2.

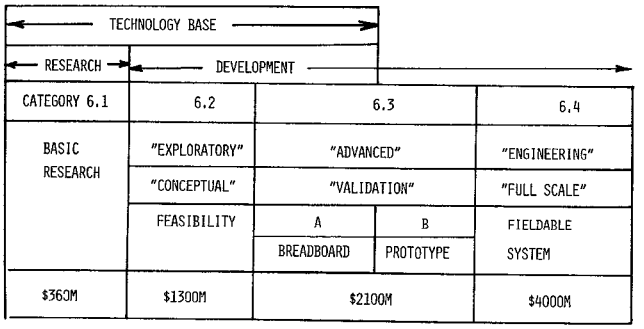

Fig. 2. DOD Technology Categories ($ for FY 77)

DOD Electronic Device Program

The DOD Electronic Device Program is divided into four major categories and one miscellaneous category, as shown in Fig. 3. Microwave Devices are divided

- o Microwave Devices
  - Tubes
  - Solid State
- o Low-Power Devices
- o Electro-Optic Devices
- o Lasers
- o Other

Fig. 3. DOD Electronic Device Program

into two major categories, tubes and solid state. We will first look at the characteristics of the whole electronic device program, before examining microwave devices more closely.

The contractual funding in category 6.2 for electron devices peaked in 1960, declined sharply till 1968, and has remained approximately constant since then, measured in constant dollars. However, it rose appreciably between 1976 and 1978. The total funding for Electronic Devices in the Technology Base in 1978 by all three Services (Army, Navy and Air Force) totals about $80 M. Add to this about $45 M of other DOD funding, and about $25 M from other Federal Agencies (NASA, NSF, DOE), and you get a total of $150 M of Federal funding for electronic devices. Industrial IR&D subsidized by Federal tax dollars amounts to maybe an additional $120 M, bringing the grand total for electronic devices funded directly or indirectly by the Federal Government to $270 M, which is split roughly 80% in industry and 20% in government laboratories.

Electronic Device Activities since 1957

Let us go back 20 years and look at what problems were being addressed at that time. Those of you who were in microwave R&D at that time will remember many of these devices, some of which are off-the-shelf items today, and some of which turned out to be blind alleys. In 1957 we worked hard on the devices shown in Fig. 4.

		$Millions
Microwave Devices	- Cathodes, Noise, Switches, Isolators, Modulators, Beams, Windows, Transmission Lines	9
	- Magnetrons, TWTs, Klystrons, Thyratrons	
	- Ferrites, Garnets	
	- Semiconductors: Negative Resistance	(0.2)
Low Power Devices	- Receiving Tubes, Capacitors, Resistors, Polymers	
	- Printed Circuit Boards, Cores, Magnetic	7
	- Micromodules, Si, GaAs, InSb, SiC	
	- Radiation Damage	
Electro-Optic Devices	- Tubes: Photoemission, Storage, Computers, Display, IR Pickup	5
Masers	- Electroluminescence	0.5
	Total	21

Fig. 4. Electron Device Thrusts - 1957

The decade 1957-1967 was a very fruitful one for electronic devices, and many basic inventions were made or mainly developed under DOD sponsorship, such as lasers, integrated circuits, microwave solid-state devices (high-frequency bipolar transistors, IMPATT's, TRAPATT's, TED or Gunn diodes), surface acoustic wave devices, magnetically tunable (YIG) filters, magnetic bubbles, magnetic bulk and surface waves, acousto-optic interactions, tunnel diodes, Josephson junctions, ion implantation, crystal bulk and epilayer growth, liquid crystals, rare earth cobalt magnets, etc.

It is too early to recognize all the major breakthroughs in the last decade (1967-1977), but the list appears to be shorter than the list for the preceding decade. Maybe we haven't recognized all the significant inventions yet. They include gallium arsenide field effect transistors (GaAs FETs), monolithic microwave integrated circuits, gyrotrons; more breakthroughs in electro-optics, such as fiber optics, integrated optics, focal plane arrays, charge transfer devices for imaging and signal processing and memories; and improved analytical techniques in surface physics.

Program Funding History

Figure 5 shows the funding in current dollars at intervals of 10 years in electronic device R&D.

	($ - Millions) FY 57	FY 67	FY 77
Microwave Devices	9	17	21
Low Power Devices (incl. integrated circuits)	7	12	20
Electro-Optic Devices (detection, display)	5	9	13
Lasers	0.5	12	14
	21.5	50	68

Fig. 5. Program Funding History

Figure 6 shows some of the devices being emphasized under the current program (6.2+6.3A only).

		FY 77	FY 78
o Microwave Devices	Tubes (TWT, CFA, Klystron, Magnetron, BWO, Cathodes, EBS, Gyrotron, Dual Mode TWT, Magnets)	7	9
	Solid State (IMPATT, TRAPATT, TED, FET, Bipolar, Power Combining, Materials)	11	11
o Low Power Devices	ICs for Logic, ICs for Memory, CCDs, SAWs, MNOS, Josephson Junctions, Magnetic Bubble, Magnetic Bloch Walls, Acousto-Optics	13	15
o Electro-Optic Devices	IR Photoconductors, IR Photovoltaics, IR Photoemitters, IR Focal Plane Arrays, Coolers, CCDs, Intensifier Tubes, Storage Tubes, Liquid Crystal Displays, Microchannels, Electroluminescence, Integrated LEDs	10	12
o Lasers	Blue Green, Chemical Metal Vapor, Gas, Integrated Optics, Fiber Optics, Injection Lasers, Laser Windows, Ring Laser Gyros	5	6

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Fig. 6 continued from previous page

		FY 77	FY 78
o Other	Reliability, Frequency Control, Power Sources, etc.	13	10
	Total	59	63

Fig. 6. Present Electronic Device Program (6.2 and 6.3A)-$M -

The ratio of direct DOD funding for microwave tubes vs. microwave solid state has decreased, but not as much as one would have supposed (from slightly over one half to slightly under one half for tubes). However, the IR&D funding (by industry) for microwave tubes has undoubtedly decreased drastically compared to IR&D for microwave solid state. The total 6.2 and 6.3A funding for microwave tubes and microwave solid state combined has remained close to eleven or twelve million dollars almost every year since 1965. It has therefore decreased substantially in real spending power. An effort is now under way to correct this downward trend.

There has been renewed interest in microwave tubes, and some of the major thrust areas are shown in Fig. 7.

- o Basic Materials and Technology
- o Cathodes
- o Interface Problems
- o Reliability
- o Bandwidth
- o Millimeter Waves
  - Gyrotrons
- o TWTs
  - Dual Mode
  - Broad Band
  - Expendable
- o High-Gain CFAs
- o Electron-Beam Semiconductor

Fig. 7. Microwave Tube Thrusts

Microwave solid state is finding application in low-noise and medium power devices. Limitations are materials, processing, and submicron geometries. Microwave integrated circuits are being investigated (Fig. 8).

- o GaAs FETs
  - Low Noise
  - High Power/Broad Band
  - Microwave Logic (A/D)
- o SAW Devices
  - Oscillators, Filters, Delay Lines, Correlators
- o Millimeter Wave Devices and Circuits
- o Monolithic MICs
- o TRAPATTS
- o Materials

Fig. 8. Microwave Solid State Thrusts

Millimeter wave systems can provide more bandwidth and resolution than microwave systems, and do not degrade in bad weather as fast as optical and infrared systems. There is renewed interest in millimeter waves, but their future standing vis-a-vis microwaves and IR is still not clear.

Issues in Microwave Technology

Some of the issues that are still unresolved in microwave technology include: microwave vs. millimeter wave vs. electro-optics; microwave tubes vs. microwave solid state; monolithic vs. hybrid integrated circuits; gigabit logic techniques; and cost and reliability. They will be examined on a continuing basis. Advances will undoubtedly be registered under "6.2" in millimeter wave devices, microwave solid-state devices, microwave integrated circuits, microwave logic, and microwave tubes. Microwave filters and passive components will be developed more in connection with systems development and company IR&D.