Chapter 4

Managing Department of Defense Technology Base Programs

INTRODUCTION

The Department of Defense (DoD) appropriation for its technology base programs[1] exceeds $8.6 billion in fiscal year 1988, of which almost half (see table 2) is funding for the Strategic Defense Initiative (SD I). This represents less than 4 percent of the entire DoD budget. Nevertheless, many inside and outside of the Pentagon consider DoD's technology base programs a crucial investment in the Nation's overall national security. The military's technology base programs consist of a broad spectrum of 'front-end" technology development, beginning with a broad base of basic research support and extending through the demonstration of technology that may make up future defense systems. The scope of interests within DoD's technology base programs ranges across diverse technological concerns from meteorology to autonomous guided missiles capable of differentiating among various targets.

In fiscal year 1988, more than half of the Pentagon's technology base program was performed by industry, another third by DoD's own in-house laboratories, and the remainder by universities. According to DoD, each of these performers plays an important part in the successful operation of its technology base program, and extensive cooperative efforts among the three groups yields a significant return on DoD's investment.

The universities perform over 50 percent of DoD's basic research activities. In addition, DoD contends that its in-house laboratories provide the Armed Services with the ability to meet special military needs that cannot be met by the Nation's industrial base. These laboratories focus attention on short- and long-term defense needs, and they enable the military to act as a smart buyer of technology and equipment. The primary role of private industry is to develop technology and apply it in new military systems.[2]

'For purposes of this study, technology base programs refer to budget categories 6.1 (basic research), 6.2 (exploratory development), and 6.3A (advanced technology development). DoD usually considers 6.1 and 6.2 as its technology base programs, with 6.1 through 6.3A normally referred to as its "science and technology programs. "

'Martin, Dr. Edith W., "The DoD Science and Technology Base Programs: Some Management Perspectives, " *Army Research, Development, and Acquisition Magazine,* Sept. -Oct. 1983, p. 3. At the time this article was written the author was DUSD(R&AT).

Table 2.—Department of Defense Fiscal Year 1988 Funding of Technology Base Programs (in millions of dollars)

	Army	Navy	Air Force	DARPA	Total
Research (6.1)	$169	$342	$198	$83	$ 902[a]
Exploratory development (6.2)	$556	$408	$557	$512	$2,033
Advanced exploratory development	$319	$227	$754	$202	$1,502
Total services and DARPA					$4,437
Strategic Defense Initiative					$3,604
Other defense agencies					$ 564
Total DoD technology base programs					$8,605

[a]This sum includes $110 million for the URI which OSD has not yet allocated among the three services and DARPA

SOURCE Office of Technology Assessment. 1988, from data supplied by the Off Ice of the Secretary of Defense.

Goals and Objectives

According to DoD, its diverse technology base programs attempt to achieve six major goals:[3]

1. *Offset Soviet Numerical Superiority.* The U.S. does not attempt to match the Soviet Union and the Warsaw bloc on a person-for-person or weapon-for-weapon basis. It relies instead on technology to achieve the desired military advantage.
2. *Keep Ahead of the Growing Soviet Threat.* Although this is increasingly more difficult, the United States must maintain its technological lead in order to offset the Soviet threat.
3. *Reduce Complexity and Costs.* The technology that is produced by the military must be designed to reduce the cost and complexity of future weapon systems.
4. *Improve Productivity of the Industrial Base.* Maintenance of a strong industrial base, vis-a-vis the Soviet Union, is one of the most important advantages for the United States.
5. *Sponsor the Highest Quality of Science and Technology (S&T) Work.* DoD must make sure that the S&T work performed by industry, universities, and its in-house labs is of the highest quality and scientifically sound.
6. *Enhance Return on Investment.* Finally, DoD always tries to receive the greateest possible return on its S&T investment.

The Department of Defense contends that the military's science and technology programs have played, and will continue to play, a crucial role in maintaining the military and civilian science and technology (S&T) base. Examples of this include:

- early development of lasers and incorporation of their unique capabilities into weapon systems;
- early development of integrated circuits and their application to mission-critical capabilities;
- development of aircraft technology which provides substantially improved capabilities in maneuverability, flight, fire control, and firepower; and
- development of the carbon-carbon composite material nosetip for the TRIDENT D-5 re-entry vehicle.

Funding Categories for DoD's RDT&E Activities

The Department of Defense does not employ the National Science Foundation's (NSF) familiar categories of basic research, applied research, and development when reporting its Research, Development, Test, and Evaluation (RDT&E) activities.[4] Instead the Pentagon uses a series of six RDT&E functional categories numbered 6.1 to 6.6. They are defined by DoD as follows:[5]

- 6.1 *Research.* Includes scientific study and experimentation directed toward increasing knowledge and understanding in those fields of the physical, engineering, environmental, biological, medical, and behavioral-social sciences related to long-term national security needs. It provides fundamental knowledge for the solution of military problems. It also provides part of the base for subsequent exploratory and advanced development in defense-related technologies and of new or improved military functional capabilities in various scientific fields.
- 6.2 *Exploratory Development.* Includes all the efforts directed towards the solution of specific military problems, short of major development projects. This type of effort may vary from fairly fundamental applied research to quite sophisticated

[3]Ibid., p. 4.

[4]According to NSF, when DoD provides NSF with its RDT&E spending levels, DoD breaks it down into NSF's three corresponding categories in the following manner: 6.1 research is reported as "basic research' 6.2 exploratory development is reported as "applied research"; and categories 6.3-6.6 are reported as "development."

[5]U.S. Department of Defense, INST 7720.16 (OPNAV 3910. 16). enclosure(3), p.2-7 and 2-8. Department of the Navy, Budget Guidance Manual, 7102.2. Quotations in the following section are from this source; the remaining material is paraphrased from this source.

breadboard hardware, study programming efforts.

> . . . The dominant characteristic of this category of effort is that it be pointed toward specific military problem areas with a view toward developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters.

- 6.3 *Advanced Development.* Includes all projects which have moved into the development of hardware for experimental or operational test. It is characterized by line item projects, and program control is exercised on a project basis. The focus of Advanced Exploratory Development (6.3A) lies in the design of items being directed toward hardware for testing of operational feasibility, as opposed to items designed and engineered for eventual Service use.
- 6.4 *Engineering Development.* Includes all those development programs being engineered for Service use but which have not yet been approved for procurement or operation. This area is characterized by major line item projects and program control by review of individual projects.
- 6.5 *Management Support.* Includes research and development efforts directed toward support of installations or operations required for general research and development use. Included would be: test ranges; military construction; maintenance support of laboratories, operations and maintenance of test aircraft and ships; and studies and analysis in support of the R&D program. Cost of laboratory personnel, either in-house or contract-operated, would be assigned to appropriate projects or as a line item in the Research, Exploratory Development, or Advanced Development Program areas, as appropriate. Military construction costs directly related to a major development program will be included in the appropriate element.
- 6.6 *Operational Systems Development.* Includes research and development efforts directed toward development, engineering and test of systems, support programs, vehicles, and weapons that have been approved for production and Service employment. 6.6 is not an official category as are 6.1-6.5, but is a term used for convenience in reference and discussion. Thus, no program element will exist numbered 6.6.

> All items in this area are major line item elements in other programs. Program control will thus be exercised by review of individual research and development effort in each Weapon System Element. Activities in categories 6.3-6.6 receive the bulk of RDT&E funding (91.5 percent in fiscal year 1987 estimated).

Funding for DoD's technology base programs is appropriated to the individual Services, SDIO, and the Defense agencies such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Nuclear Agency (DNA). As table 2 indicates, in fiscal year 1988, SDIO supported the largest technology base program, followed by the Air Force Army, Navy, and DARPA.

An Overview of Defense Research Programs (6.1)

The Armed Forces have supported research since the early days of the Nation. The 1804 expedition of Lewis and Clark, for example, was funded by the Army. With the establishment of the Office of Naval Research (ONR) in 1946, the military became the first Government organization to support a major program of university-based basic research. This commitment continued with the establishment of the Army Research Office (ARO) in 1951, and the Air Force Office of Scientific Research in 1952. The Advanced Research Projects Agency (ARPA, later DARPA) was established in 1958 as part of the U.S. response to Sputnik.

DoD funded the bulk of federally sponsored research prior to the establishment of such Federal research agencies as the National Science Foundation and the National Aeronautics and Space Administration. In the 1950s and early 1960s, DoD sponsored about 80 percent of all federally funded basic research. However although DoD funds about 66 percent of all Federal R&D, it is the fourth largest supporter of basic research, accounting for approximately 13 percent of all federally sponsored basic research.

In fiscal year 1988 DoD will spend about 2.1 percent of its RDT&E budget ($902 million) on basic research. This is down from an average of 4.6 percent in the 1960s and 3.6 percent in the 1970s. During fiscal year 1988, approximately 50 percent of DoD's research will be performed by universities, with another 30 percent by DoD's in-house laboratories, and the remaining 20 percent by industry and nonprofit organizations.

The Department of the Navy will support the largest research program in fiscal year 1988, funding 37 percent of all DoD's research. The Army and Air Force will support about 19 and 23 percent respectively, with DARPA and the other Defense agencies supporting the remaining 21 percent.

The Pentagon views its research program as a crucial source of its future technology. However, DoD research activities differ from other technology base activities because research is not necessarily expected to result directly in a military product. The Services support research into the nature of basic processes and phenomena, and contend that they select research projects based on the quality of science and their potential relationship to the DoD mission.

The three Services and DARPA support research activities in such fields of science as:

- physics
- astronomy
- electronics
- mathematics
- mechanics
- materials
- oceanography
- atmospheric sciences
- behavioral sciences
- radiation sciences
- astrophysics
- chemistry
- computer science
- energy conversion
- aeronautical sciences
- terrestrial science
- medical and biological sciences

Work in these fields is applied to space technology, computer science, electronics, surveillance, command and control, communications, propulsion, aerodynamics, night vision, chemical and biological defense, structures, medical and life sciences, and other areas of military importance.[6]

Most successful research programs lead to further efforts in exploratory development (category 6.2) which focus on more applied configurations with military relevance. This research and development process led, for example, to the injection of laser technology into military systems. The laser was primarily supported by DoD soon after the time of its invention, when its potential military relevance appeared quite remote.

The Office of the Secretary of Defense (OSD) and the Services contend that research accomplishments are transferred or quickly passed onto the military R&D community and potential laboratory program managers.

Extramural contractors, primarily universities and industry, are not expected to justify their (6.1) research proposals in terms of possible DoD applications. However, in-house researchers, because of their laboratory association, are expected to demonstrate a closer association to specific military applications. The most important criterion for funding research is the quality of science, followed by its potential relationship to the DoD mission. Other criteria include:

- the potential of the proposed research to lead to 6.2 work;
- whether a civilian R&D agency should support the proposed research;
- the possibility that the research will lead to radically new scientific discoveries;
- the track record of the researcher(s) submitting the proposal; and

[6] Col. Donald I. Carter, "The Department of Defense Statement on Science in the Mission Agencies and Federal Laboratories," before the Task Force on Science Policy of the House Committee on Science and Technology, Oct. 2, 1985, p. 7.

- the extent to which a proposal fits into a particular Service's 6.1 funding priorities.

The basic research programs in the three Services are comprised of three major program elements (PE):[7] Defense Research Science; the In-House Laboratory Independent Research Program (ILIR); and the University Research Initiative (URI). The Defense Research Science program is the largest of the three programs, making up 90 percent of the 6.1 budget. At 6 percent of the research budget, ILIR is designed to give laboratory directors flexibility in order to take advantage of new technological opportunities and to help maintain a research base in the laboratories. (DARPA and the Army do not support ILIR programs.) The remaining 4 percent of the research budget is devoted to the URI program.

Pursuant to the 1984 Competition in Contracting Act, all of the Services and DARPA publish an annual broad agency announcement (BAA). The BAA outlines the specific research interests of each Service and DARPA, and the procedures for submitting research proposals. DoD contends that all proposals falling within the guidelines of each BAA are considered competitive and satisfy the Act.

DoD believes that supporting 6.1 work is important for its in-house laboratories. By supporting the military's research program, DoD feels laboratory researchers are able to keep abreast of new discoveries and engage in important interactions with the scientific community. According to DoD, laboratory performance of research increases the technical abilities of the laboratories and helps to attract imaginative scientists and engineers.

Technical Review of Research Proposals and Programs

Each of the Services, and DARPA, conducts an extensive technical review of all research proposals. The Army Research Office subjects proposals to a three-level technical review process: a peer *review* in the external scientific community for technical excellence, an Army laboratory review both for excellence and military relevance, and an ARO internal review to make a final funding decision. The Services encourage researchers to discuss their proposal ideas with the appropriate DoD technical person before submitting a formal proposal. Those researchers who follow this suggestion have an approximate 50-percent success rate, compared to a lo-percent funding rate of proposals received without prior contact.

The Navy's technical review is completed primarily in-house by their scientific officers. Of the three Services' research programs, the Office of Naval Research has the largest number of staff scientific officers, about 80. Due to a smaller professional staff, the Army Research Office (ARO) and the Air Force Office of Scientific Research (AFOSR) rely primarily on outside review of their research proposals although they also use in-house expertise to review proposals. (Each has about 40 professional people located at its research office.) The National Academy of Sciences (NAS) has a contract with the ARO and AFOSR to arrange formal technical reviews of research proposals. DARPA relies primarily on the three Services and the external scientific community to review its research proposals.

In most cases, the Service laboratories form technical review panels, made up of the laboratory director and various technical program directors, to decide which research proposals will be funded within the laboratory. The Naval Research Laboratory, for example, uses a Research Advisory Committee, consisting of the laboratory and program directors, that determines which in-house research proposals will be supported.

An Overview of DoD's Technology Base Activities in the Laboratories

The Department of Defense laboratories perform research and development in diverse areas of science and technology in support of military and civil works programs of DoD.

'The PE is the basic building block in DoD's program, planning, and budgeting system (PPBS). There are approximately 180 PE's in DoD's entire technology base program, with each PE consisting of all costs associated with a research activity or weapon system.

There are currently 68 DoD RDT&E laboratories (31 Army, 23 Navy, and 14 Air Force) that have a combined annual cash flow of nearly $10 billion for technology base and other development activities. The responsibilities and operations of the various laboratories differ within the three Services in order to meet their individual mission requirements. DoD's laboratories actually perform only about one-third of the technology base activities, while industry performs over 50 percent and the Nation's universities and nonprofit organizations perform the remainder.

The Pentagon contends that its laboratories play a crucial role in solving science and engineering problems, deficiencies, and needs that are unique to the military. DoD states that the primary purpose of its laboratories is to develop new technologies to support each of the respective Service's missions. According to DoD, the role of the laboratories in the development and improvement of technology and weapons systems is fundamental to improving national security. DoD believes that the laboratories have a responsibility to maintain a strong continuity of scientific activities, free from commercial pressures, directed toward meeting specific military needs. Further, according to DoD, the laboratories provide a fast reaction capability to solve immediate critical problems that may confront the Services. Other responsibilities include the following:

1. ensure the maintenance and improvement of national competence in technology areas essential to military needs;
2. avoid technological surprise and ensure technological innovation;
3. pursue technology initiatives through the planning, programming, and budgeting process; allocate work among private sector organizations and government elements;
4. act as a principal agent in maintaining the technology base of DoD;
5. provide material acquisition and operating system support;
6. stimulate the use of technical demonstrations and prototypes to mature and exploit U.S. and allied technologies; and
7. interface with the worldwide scientific community; provide support to other government agencies.[9]

The Pentagon asserts that its technology base capabilities should serve as a strong complement to the civilian technology base, as emphasized in a recent DoD report to the Senate Armed Services Committee:

> A strong free enterprise economy and industrial base–here and abroad–are the essential underpinning of our defense posture. Investment in our technology base and maintenance of our technology strength are critical to the long term security of the U.S. and our allies.[10]

Over the past several years DoD officials have been trying to resolve a number of difficult laboratory issues. The Pentagon has been struggling with such concerns as improving communications within and among the different laboratories, increasing the management flexibility of the individual laboratory directors, meeting scientific and technical personnel needs, upgrading facilities, developing mechanisms for evaluating the performance of the laboratories, and improving DoD's overall management of its laboratories.

Special Technology Base Initiatives

DoD has initiated a number of special programs to help address specific technology base problems. Most of these initiatives center around such concerns as communication between DoD and various research performers, scientific communications and technology transfer, and support of the research infrastructure.

In 1982, DoD established the 5-year, $150 million University Research Instrumentation

[8]There is about an equal number of other centers that do not perform traditional RDT&E activities, but rather are special facilities with very specific missions, such as flight testing new or refurbished aircraft. The R&D activities of DoD's laboratories are discussed further in chapter 5.

[9]U.S. Department of Defense, "Report (for the Committee on Armed Services) on the Technology Base and Support of University Research, " Mar. 1, 1985, p. 42.

[10]Ibid., p. 53.

Program (URIP) to improve the capability of universities to perform research in support of the national defense. This program provides funding for large items of equipment ($50,000 to $500,000) that would not be funded in a typical research grant.[11] This program was considered a success by DoD. But judging by the response, it will not come close to meeting all the instrumentation requests; in the first year alone, it received 2,500 proposals seeking a total of 646 million dollars' worth of equipment.

In 1983, at the recommendation of the Defense Science Board, DoD established the DoD University Forum. The Forum consists of an almost equal number of DoD and university members and was originally co-chaired by the Under Secretary of Defense for Research and Advanced Technology and the President of Stanford University. The Forum has issued reports dealing with such subjects as scientific secrecy and technology export control, engineering and science education needs, and DoD's response to those needs. More recently, the forum's working group on engineering and science education issued a report which endorsed the major components of the University Research Initiative (URI) to foster greater DoD-University cooperation.

According to the Department of Defense, the URI would "address some of the concerns expressed by Congress regarding DoD support for the infrastructure of science and technology in the United States, " particularly at colleges and universities.[12] DoD proposed to spend $25 million in fiscal year 1986 and $50 million in fiscal year 1987 for the University Research Initiative. Congress responded by appropriating $88.5 million in fiscal year 1986, $35 million in fiscal year 1987, and $110 million in fiscal year 1988.

DoD's URI program consists of two major program elements. The first element consists of multidisciplinary research contracts designed to enhance interdisciplinary research efforts between universities, industry, and DoD laboratories. Generally, these contracts will receive support for 3 to 5 years, with review and evaluation after 3 years. These research centers will conduct research in a range of disciplines (mathematics, engineering, and the physical, biological, and social sciences) important to the Pentagon. The centers will increase overall defense funding for high risk basic research in support of critical defense technologies, as well as continue support (in place of URIP) for equipment and instrumentation.[13]

The second major URI program element is the "Programs to Develop Human Resources in Science and Engineering. " This program element is designed to increase DoD's support for fellowships, postdoctoral, young investigators, and scientific exchange programs, in order to promote interaction between scientific and engineering personnel in DoD laboratories and universities conducting DoD-sponsored research.

DoD asserts that its laboratories are in the forefront of the effort to transfer technological expertise from the Federal Government to State and local governments and private industry. The Federal Laboratory Consortium for Technology Transfer was originally established by the Department of Defense in 1972. Further, in response to the Stevenson-Wydler Technology Innovation Act, the Department of Defense established its domestic technology transfer program under the responsibility of the Deputy Under Secretary for Research and Advanced Technology. The primary goal of this effort is to accelerate the domestic transfer of unclassified technical and scientific expertise to both the university community and the private sector.

DoD sponsors a number of educational programs to help ensure an adequate supply of

[11] According to DoD, funding for a typical l-year single investigator research contract would fall in the range of $50,000 to $100,000.

[12] Col. Donald I. Carter., USAF Acting Deputy Under Secretary of Defense for Research and Advanced Technology, Testimony Before the Subcommittee on Research and Development of the House Armed Services Committee, Apr. 2, 1985.

[13] U.S. Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, fiscal year 1986 University Research Initiative Program Overview, December 1985, p. 2.

highly trained scientific and engineering personnel. All three Services support a large number of science and engineering graduate students as well. DoD's direct funding for research at universities provides the Pentagon with its largest base of graduate student support. A 1980 study, conducted by the Office of Naval Research, estimated that on average a million dollars of university research funding supported 10 to 15 full-time or part-time graduate students. Based on those figures, the Pentagon estimated that it supported between 4,000 and 4,500 graduates students in fiscal year 1987.

At the graduate level all three Services sponsor activities to increase the supply of scientific personnel. The fellowship programs of both the Army and Navy support graduate students in such fields as computer sciences, electrical engineering, and life sciences. The Air Force fellowship program is aimed at more mission-specific activities, sponsoring students in such areas as advanced composite structures and aircraft propulsion technology. According to DoD, the Services supported about 200 graduate fellowships in fiscal year 1987; of this total, the Navy supported about 145. The Services also provide opportunities for faculty and undergraduate and graduate students to conduct research at various DoD laboratories during the summer months.

Planning

All of the Services conduct an extensive annual top-down, bottom-up planning exercise in order to develop a 5-year program objective memorandum (POM) and annual technology base investment strategy. From the top the Services receive the annual Defense Guidance Manual, prepared by the Office of the Secretary of Defense, which provides them with guidance on developing their entire RDT&E programs. Planning usually begins with a review and evaluation of the previous year's research activities. When this review is completed, the Services decide which activities to continue, which to transition (e.g., from 6.1 into 6.2 programs), and which activities to stop. Each of the Services develops an annual technology base strategy, such as Army's Mission Area Material Process, or utilizes special studies—such as the Air Force Forecast II project—which serve as major guides for their respective research programs.

The laboratories attached to a particular Armed Service contribute to its technology base plan. Outside advisory bodies such as the National Academy of Sciences, the National Science Foundation, individuals in the scientific community, and in-house technical directors and their respective staffs also make recommendations. The Services also have scientific advisors or science boards that participate in planning activities. The individual Services can also request that their science boards conduct a review of some particular area of the technology base programs to assure its scientific merit and/or responsiveness to particular Service needs. There are inter-Service cooperative groups, such as the Joint Logistics Commanders and the Joint Directors of Laboratories, which meet and review past and future laboratory activities to reduce duplication while increasing awareness of existing laboratory activities.

Finally, DoD has an elaborate scientific and technical advisory mechanism, with ad hoc and permanent scientific advisory committees at many levels, to advise individual laboratories, military Service chiefs, and OSD. At the level of the Office of the Secretary of Defense, the Defense Science Board deals with both specific and broad policies that address such issues as scientific manpower, defense industrial preparedness, the quality of the technology base, technology transfer, and standardization of weapon systems in NATO. Each branch of the military also has a scientific advisory body analogous to the DSB: the Army Science Board, the Naval Research Advisory Committee, and the Air Force Scientific Advisory Board.[14]

"Science Policy Study Background Report No. 8, "Science Support by the Department of Defense, " prepared by the Congressional Research Service for the Task Force on Science Policy, Committee on Science and Technology, U.S. House of Representatives, 99th Congress, p. **405.** Hereafter referred to as "Science Support by the Department of Defense. "

OVERSIGHT AND MANAGEMENT IN THE OFFICE OF THE SECRETARY OF DEFENSE

The Office of the Secretary of Defense exerts oversight responsibility for all of DoD technology base programs. Oversight refers to the process of formulating and developing policy guidance for a particular program, in this case DoD's technology base programs. It includes: developing an investment strategy for a particular program; assigning management responsibility for the program; coordinating research programs; establishing policy; developing program evaluation procedures; and recommending appropriate programmatic changes.

OSD *is* primarily concerned with making sure that DoD's technology base programs are well balanced and reflect the overall needs of DoD. In addition, the Services and DARPA each assign specific individuals within their respective organizations oversight responsibilities for technology base programs. At this level, individuals responsible for oversight are primarily concerned with protecting and helping to manage and coordinate their organization's technology base programs.

Programmatic management involves the direct day-to-day management of a certain technology base activity. Programmatic management includes responsibility for the successful completion of an R&D activity, including: timely completion of R&D tasks; meeting projected costs; evaluation of R&D activities; and facilitating the transitioning or phasing out of research activities. The Services, DARPA, and SDIO each assign specific individuals, within their respective organizations, day-to-day management responsibility of various technology base activities.

As a result of the Military Reform Act of 1986 (sometimes referred to as the Goldwater-Nichols Act), DoD has reorganized the management of its RDT&E activities. The Act abolished the office of Under Secretary of Defense for Research and Engineering and replaced it with the Under Secretary of Defense for Acquisition (USD(A)). The legislation also re-created the Director of Defense Research and Engineering (DDR&E), who reports to the USD(A).

Until 1986, the Under Secretary of Defense for Research and Engineering had responsibility for the research and development activities of DoD and chaired the Defense System Acquisition Review Council (DSARC), which made decisions about which major weapon systems to purchase. In 1985 the functions of the Office of the Under Secretary were trimmed when Secretary of Defense Weinberger removed from the office "primary responsibility y for overall production policy and some key production decisions. " The effect of the reorganization, according to *Science* magazine, was to drive a wedge between those responsible for research and development and those responsible for production, with the hope that fewer faulty weapon systems would get from the laboratory to the factory.[15] The President's Private Sector Survey on Cost Control (known as the Grace Report) and the Packard Commission had criticized the combination of research with production. Consequently the Goldwater-Nichols Act created the Under Secretary for Acquisition (USD(A)) and the DDR&E to maintain a separation between R&D and acquisition decisions. 'G

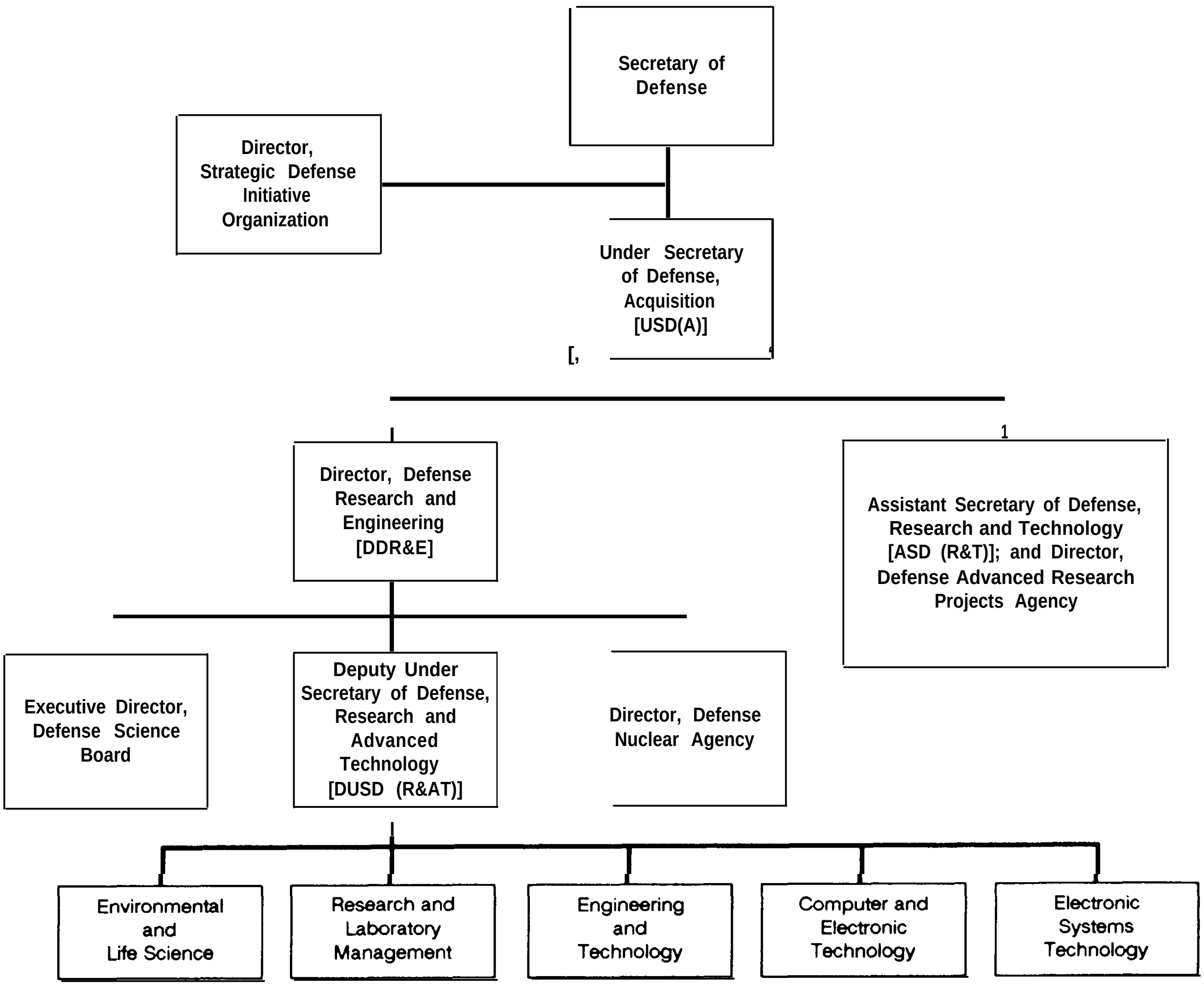
The USD(A) has oversight responsibility for DoD's technology base program, with the exception of SDIO (see figure *2)*. The DDR&E has oversight responsibilities for the Services and the DNA's technology base programs.

According to the USD(A), the DDR&E has five primary responsibilities: 1) to oversee development and acquisition of weapon systems through full scale engineering development; 2) to oversee force modernization; 3) to oversee design and engineering; *4)* to oversee develop-

[15]R. Jeffrey Smith, "DoD Reorganizes Management, " *Science,* Feb. 8, 1985, p. 613.

"For further details see Science Support by the Department of Defense, " p. 63.

Figure 2.-Management of the Department of Defense Technology Base Program



SOURCE: Office of Technology Assessment, 1988

mental test and evaluation; and 5) to oversee basic research, exploratory development, and advanced technology development. As figure 2 indicates, the Director of the Defense Nuclear Agency and the Executive Director of the Defense Science Board, which is the principal advisory body within the OSD, also report to the DDR&E.

As a "corporate guardian" of DoD's entire technology base program (except for SDIO), the DDR&E is responsible for ensuring that the technology base programs of the three Services, DARPA, and DNA are following overall technology base guidance developed by the OSD. The DDR&E also acts to ensure that disagreements pertaining to technology base responsibilities and priorities are settled in a way that best represents the science and technology interests of the Department of Defense.

According to DoD, the Assistant Secretary of Defense for Research and Technology—ASD(R&T)—will also serve as the Director of the Defense Research Projects Agency (DARPA). The Director of DARPA reports to the USD(A), but will work closely with the DDR&E to coordinate DARPA's technology base programs, which are contracted through and managed primarily by the three Services. Prior to the recent reorganization, the Deputy Under Secretary of Defense for Research and Advanced Technology (DUSD(R&AT)) reported directly to the Under Secretary of Defense Acquisition (USD(A)). However, the DUSD (R&AT) now reports to the USD(A) through the DDR&E. The primary responsibility of the DUSD(R&AT) office is to provide oversight for the three Services' technology base programs, and to serve as their DoD point of contact. The primary functions of R&AT are to: structure the technology base program across Service lines, in order to eliminate overlaps and gaps; resolve technical differences; and enhance return on investment.

The R&AT office also develops the planning, programming, and budgeting system (PPBS), writes the technology base portion of the Defense Guidance Manual, and if required responds to the Services' Program Objective Memoranda. The R&AT office must also review the 2-year budget proposals of the Services and assure that those expenditure plans have the appropriate balance among the various proposed programs. Finally, the DUSD (R&AT) is supposed to work continually with the Services to help them achieve mutual science and technology interests.

With overall guidance from the Office of the Secretary of Defense and the R&AT office (primarily through the annual publication of the Defense Guidance Manual), the three Services and DARPA formulate their technology base programs. Determining the scope of technology base work involves an evaluation of the operational needs of each participant and the technological opportunities for meeting those needs. The needs are primarily derived through a comparison of the future projected military threat with planned U.S. military capability and doctrine. Finally, the R&AT office must be sure the Service technology base programs establish new research initiatives in order to meet the long-term science and technology requirements of the three Services.

The Research and Advanced Technology office has itself recently been reorganized into five major directorates, as shown in figure 2. There are approximately 30 professional scientists and engineers spread among the five directorates. The Research and Laboratory Management Directorate is responsible for: oversight of the Service research (6.1) programs; oversight of the DoD laboratories; related research and development in the industrial sector, including Independent Research and Development (IR&D);[17] and the flow of scientific and technical information. The office meets with representatives from the three Services, DARPA, and SDIO to: coordinate research-related policymaking; help facilitate inter-Service cooperation; suggest solutions to managerial problems; and address urgent research needs. In addition to coordinating research in-house, the Research and Laboratory Management office also works with different Federal R&D agencies, such as the National Science Foundation (NSF), and with the U.S. scientific community. The remaining four directorates have oversight responsibilities-and in one instance management responsibility—for exploratory (6.2) and advanced technology development (6.3A) conducted in-house by DoD labs or extramurally by outside contractors.

The Electronic Systems Technology Directorate is responsible for oversight of programs in surveillance, communications, electronic warfare, optical countermeasures and tactical directed energy weapons. In the area of search and surveillance, concepts are being refined to improve day/night/all-weather capabilities. This particular research complements thrusts in precision-guided weapons and activities to develop automatic high-resolution target identification, classification, and tracking technology.

The Engineering Technology Directorate is often referred to as the "firepower and mobility" directorate, with oversight responsibility for four related areas: combat vehicles, propul-

[17] See ch. 3 for a discussion of IR&D.

sion and fuels, conventional weapons, and materials and structures. One of the major goals of the directorate is to facilitate technology transition through advanced technology demonstration to better match the technological needs of the various Services. Consequently, this directorate has oversight responsibilities for a large portion of DoD's advanced technology development activities (6.3A). This directorate also has responsibility for spacecraft propulsion and the National Aerospace Plane, for logistics R&D, and for the Army Corps of Engineers laboratories.

The Environmental and Life Sciences Directorate deals with four supporting disciplines: training and personnel technology; medicine and life sciences; chemical warfare and chemical/biological defense; and environmental factors. In the area of training, work is being conducted in the area of computer-based training and performance aids for operations and maintenance tasks. In the environmental sciences, major efforts involve modernizing data acquisition and processing capabilities and the upgrading of DoD's radar technology, tactical sensors, and tactical decision-aid capabilities.

The Computer and Electronics Technology Directorate operates differently than the other four directorates. This directorate is what DoD refers to as a "thrust directorate" because it manages considerable program funding. In addition to oversight responsibilities, its director has a direct management role in the planning, execution, and evaluation of various programs. The director has direct management responsibility for the SEMATECH program,[18] the Very High Speed Integrated Circuit (VHSIC) program, the Microwave/Millimeter Wave Monolithic Integrated Circuit (MIMIC) program, the Software Technology for Adaptable Reliable Systems (STARS) program, and several others.

DoD contends that this directorate's direct management responsibilities address three important management needs: 1) to focus the military's needs on computer and electronics-related technology, 2) to ensure that both the hardware and software receive appropriate attention, and 3) to place more emphasis on the transition of computer and electronics technology to operational systems.

[18]The SE MATECH program will attempt to rectify the problem of U.S. competitiveness in worldwide semiconductor markets by pooling the resources of the semiconductor industry, with assistance from the Federal Government. These resources will be used to create a central production facility from which new manufacturing processes would be made available to the U.S. semiconductor industry. Congress has agreed to begin funding for this proposal and has provided $100 million in funding (to be managed by DoD) for fiscal year 1988.

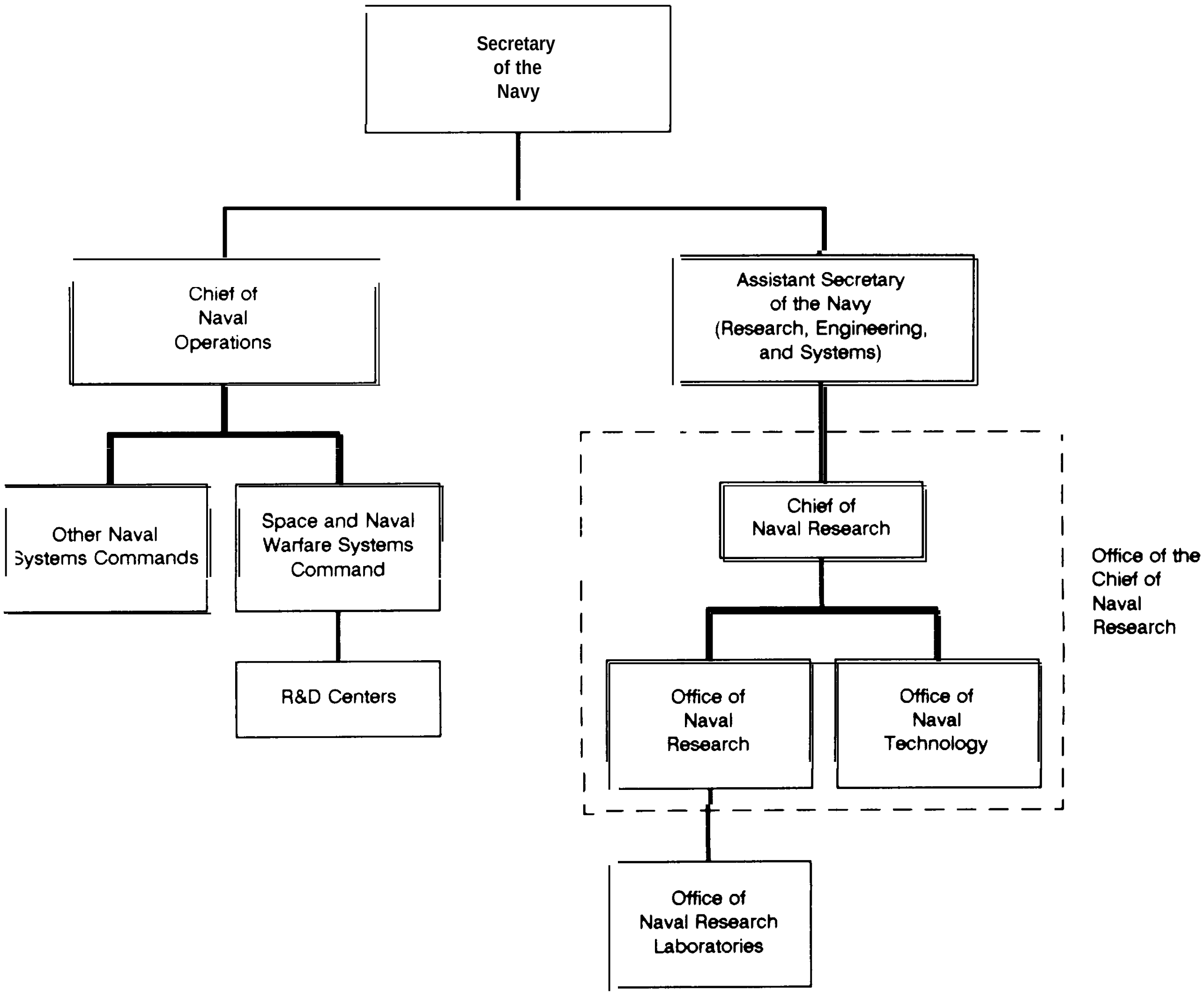
THE DEPARTMENT OF THE NAVY

The Office of Chief of Naval Research (see figure 3) is responsible for the Department of the Navy's basic research (6.1) and exploratory development (6.2) programs. The Chief of Naval Research reports to the Assistant Secretary of the Navy for Research, Engineering, and Systems and to the Chief of Naval Operations for policy guidance, planning, and execution of the Navy's basic research and exploratory development programs. The Chief of Naval Research serves as the scientific advisor to the Chief of Naval Operations (CNO) and the Commandant of the Marine Corps (CMC). Since 1985 he has also had oversight responsibility for all Navy's laboratories.

Management of the Navy's Research (6.1) Program

The Office of Naval Research (ONR, see figure 4) is responsible for the daily activities of the Navy's research programs. The director of ONR reports to the Chief of Naval Research, who is ultimately responsible for planning, review, and approval of the Navy's various research activities. ONR was established by Congress in 1946 as the first Federal organization to support university-based basic research. ONR was responsible for developing a number of mechanisms which are still in use today to

Figure 3. –Navy Organization for Science and Technology



SOURCE: Office of the Chief of Naval Research

support research at the Nation's universities. They include:

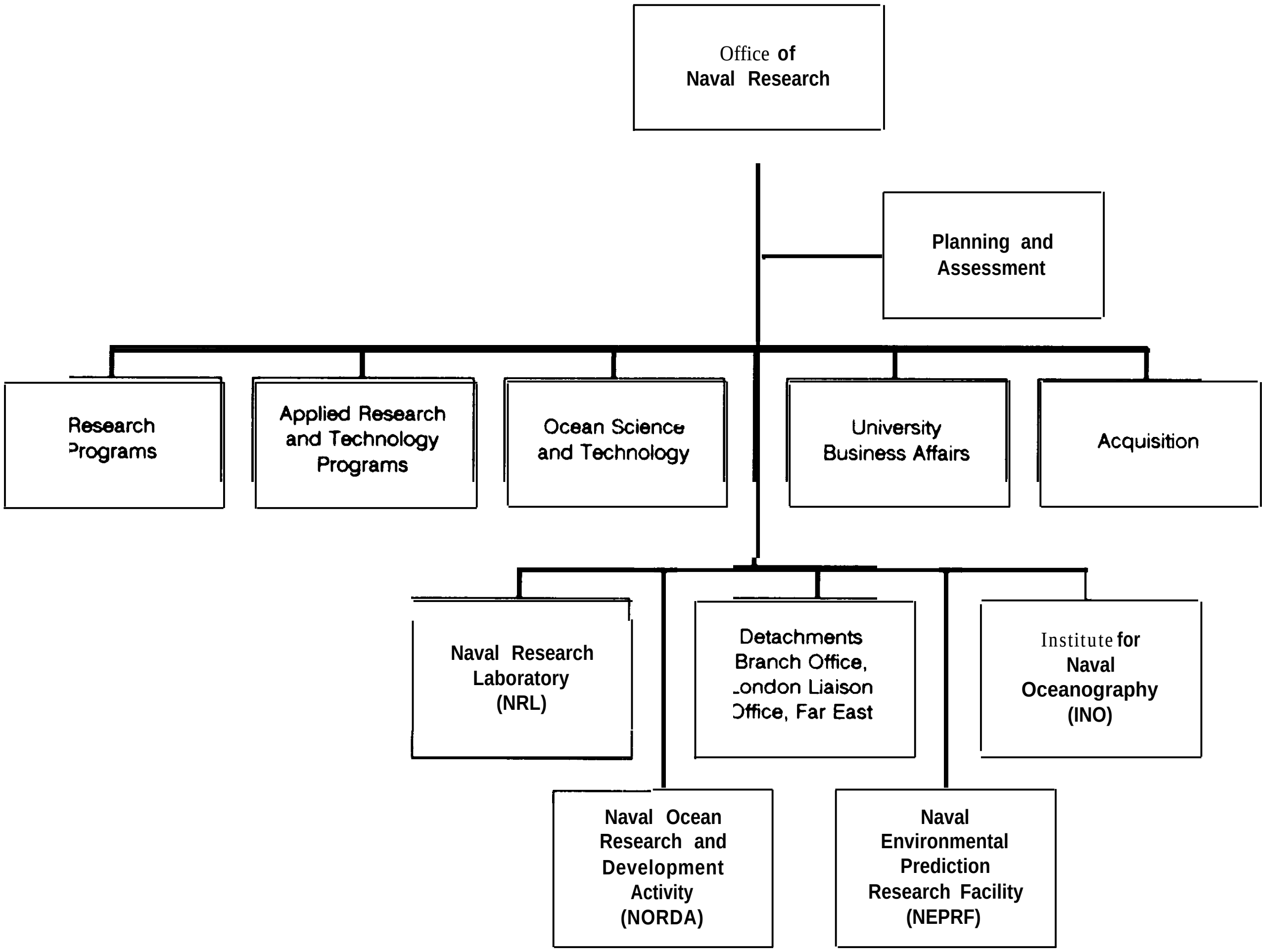
- funding project grants for individual researchers at colleges and universities;
- establishing a peer review process to evaluate research proposals;
- purchasing of expensive specialized equipment;
- funding the construction of large facilities, operated by a consortium of universities; and
- funding for special-purpose research at institutions such as Woods Hole Oceanographic Institute.[19]

According to ONR, the primary goals of its research programs are:

- to sustain U.S. scientific and technical superiority for Naval power and security;

[19]U.S. Congress, House Committee on Government Research, Federal Research and Development Programs Hearings, Nov. 18., 1963, p. 33.

Figure 4.-Office of Naval Research



SOURCE: Office of Naval Research

- to provide a source of new concepts and technical options;
- to support theoretical and experimental research in each directorate;
- to retain a vigorous scientific manpower and laboratory base; and
- to apply the results of research to Naval warfare and warfare support areas.

The research program of ONR supports a broad spectrum of scientific disciplines. ONR plans to fund 342 million dollars' worth of research in fiscal year 1988. Sixty percent of those funds will go to universities. ONR's four laboratories (the Naval Research Laboratory, the Naval Oceanographic Research and Development Activity, the Institute for Naval Oceanography, and the Navy Environmental Prediction Research Facility) will receive 21 percent; other Navy laboratories will get 12 percent; and for-profit and nonprofit organizations will receive the remaining 7 percent.

Founded in 1923, the Naval Research Laboratory (NRL) is the principal laboratory of ONR. It receives almost 90 percent of the 6.1 funds that go to the ONR laboratories. This research funding is about 24 percent of the laboratory's total in-house funds, and it plays a major role in NRL's total in-house operation.

The NRL performs and supports research in a broad range of areas including computer science and artificial intelligence, directed energy weapons, electronic warfare, space science and technology, materials, radar, information management, surveillance and sensor technology, environmental effects on Naval systems, and underwater acoustics.

ONR relies on four major research directorates to carry out its contract research programs: Mathematics and Physical Sciences, Environmental Sciences, Engineering, and Life Sciences. As might be expected, the directorate which receives the largest share of research funds is Environmental Sciences, with its focus on oceanography activities. The Navy's Ocean Sciences Division covers the range of disciplines from physical oceanography of both the open ocean and coastal zones, through ocean biology and ocean chemistry, to marine meteorology.

A fifth ONR directorate, the Applied Research and Technology Directorate, has primary responsibility for adapting and extending generic basic research toward applied research, thereby helping to transition research results into the Navy's exploratory development program. This directorate is also responsible for working closely with the Navy's exploratory development program in order to identify and implement high-leverage opportunities for joint research and exploratory development funding. The Navy is the only Service that operates a research directorate with this type of responsibility.

The Applied Research and Technology Directorate is also an agent and a project manager for selected programs sponsored by the Deputy Chief of Naval Operations for Submarine Warfare, DARPA, the Strategic Defense Initiative Organization (SDIO), and other defense organizations and industry. The ONR, with the assistance of this directorate, manages the largest SDIO basic research program of the three Services. ONR expects to manage between $80 and $90 million, primarily in the research category, for SDIO in fiscal year 1988.

Forty percent of ONR's research program consists of Accelerated Research Initiatives (ARIs) designed to concentrate resources in specific areas of research which offer a particularly attractive scientific or Naval opportunity. ARIs, which are normally funded for 5 years, are sprinkled throughout the four research directorates and the laboratories of ONR. These initiatives represent an accelerated or enhanced program in a basic scientific area which is potentially attractive to future Navy needs.

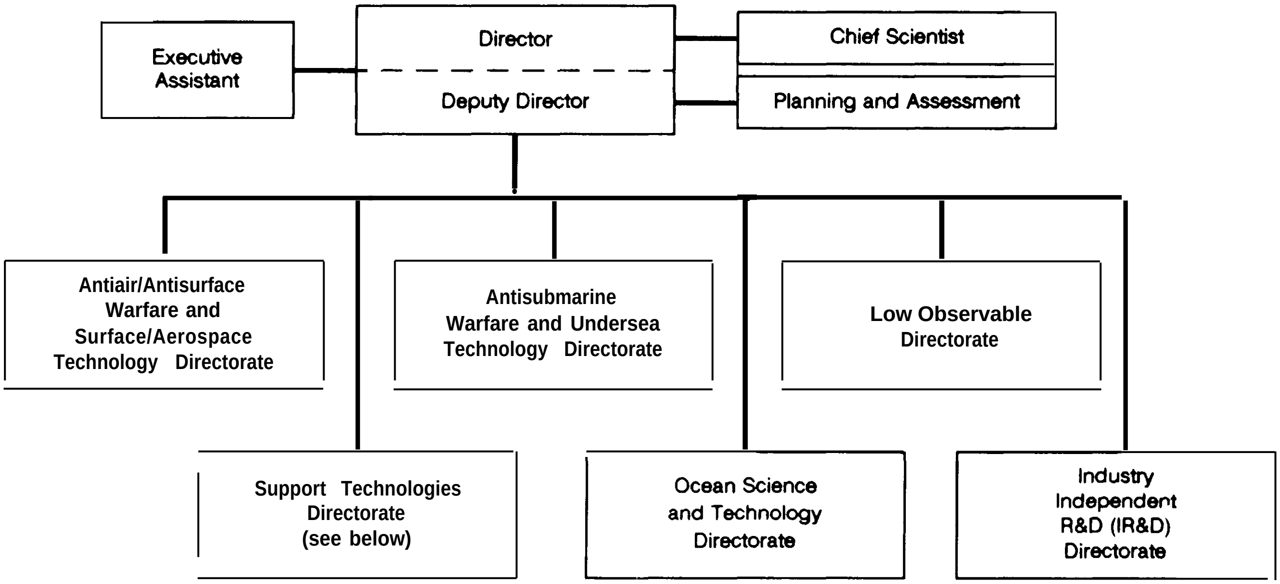
Some of the ARI research areas include: arctic oceanography, composites, interracial science, and electrochemical properties of membrane proteins as the basis of specialized cellular functions. ARIs are selected from research options developed by the scientific community and by ONR's scientific officers, and are reviewed and ranked as part of ONR's annual research planning and budgeting process. ARI selection is based on how well the proposed activity meets the goals of the Navy's research program and is done through an expert panel-based peer review process.

Management of the Navy's Exploratory Development and Advanced Technology Development Programs (6.2 & 6.3A)

The Navy's entire exploratory development program is managed by the Office of Naval Technology (ONT) within the Office of Chief of Naval Research. ONT (see figure 5) was created in 1980 by the Secretary of the Navy to "provide for a more clearly defined process of planning, execution and transition of programs within the technology base and into advanced technology development . . ." ONT currently has a professional staff of 55 people to carry out its responsibilities.[20]

[20]From 1980 through 1985, ONT reported to the Deputy Chief of Naval Material (Technology) [DCNM(T)]. In May 1985, when the Naval Material Command was abolished, the CNR was assigned the additional responsibility of managing those Naval R&D Centers that had reported to the Chief of Naval Material. In 1986, management of the Navy's R&D centers were placed under the newly created Space and Naval Warfare Systems Command (SPAWAR).

Figure 5.—Office of Naval Technology



Support Technologies Include:

- **Command, Control, and Communications**
- **Mission Support Technologies**
  (Personnel and Training; Biomedical; Logistics; Chemical/Biological/Radiological Defense)
- **Systems Support Technologies**
  (Electronic Devices; Materials; Human Factors; Oceanography; Computer Hardware, Software, and Architecture; Artificial Intelligence)

SOURCE: Office of Naval Technology

ONT is primarily responsible for all programmatic oversight of the Navy's exploratory development program, which includes such activities as program planning, approval, funding, review, and evaluation. One of the most important activities of the ONT is the development of the investment and mission area strategies, which are the heart of the 6.2 program management system. These strategies are developed in consultation with OSD, the Office of the Secretary of the Navy, the CNO, the Commandant of the Marine Corps, ONR, the Director of Navy Laboratories at the Space and Naval Warfare Systems Command (SPAWAR), and the other Naval System Commands.

The Director of Navy Laboratories (DNL) at SPAWAR, where about half of the ONT's 6.2 program is performed, is responsible for establishing laboratory policy and management procedures. This includes resolving disputes-between the laboratories involving research emphasis and responsibilities. However, the DNL does not have any responsibilities for the development and selection of research projects that are supported by the various SPAWAR laboratories.

Through its R&D Centers, the Navy performs much more of its 6.2 and 6.3A program in-house than do the other Services, for which 6.3A work is primarily performed by industry. Navy R&D Centers have a much stronger emphasis on development activities beyond the tech base than do the laboratories of the other Services.

In fiscal year 1988, the Navy will support the smallest exploratory development program of the three Services, conducting 59 percent of its 6.2 activities in-house. Industry will conduct 31 percent, universities 7 percent, and the remainder will be conducted by other government agencies. Although the Navy has over 20 laboratories, the majority of 6.2 and 6.3A activities are performed by the eight SPAWAR R&D Centers and the three ONR laboratories.

As figure 5 indicates, ONT consists of six major directorates. Three of them—the Antiair/Antisurface Warfare and Surface/Aerospace Technology Directorate, the Support Technologies Directorate, and the Antisubmarine Warfare and Undersea Technology Directorate—fund about 80 percent of the Navy's 6.2 program. The remaining three directorates have specific responsibilities primarily with oversight and coordination of related exploratory development programs.

The Industry IR&D Directorate is responsible for all oversight of the Navy's IR&D programs. The office is responsible for working with industry insetting IR&D priorities, evaluating IR&D activities, and maintaining yearly records of what type of IR&D activities are actually conducted.

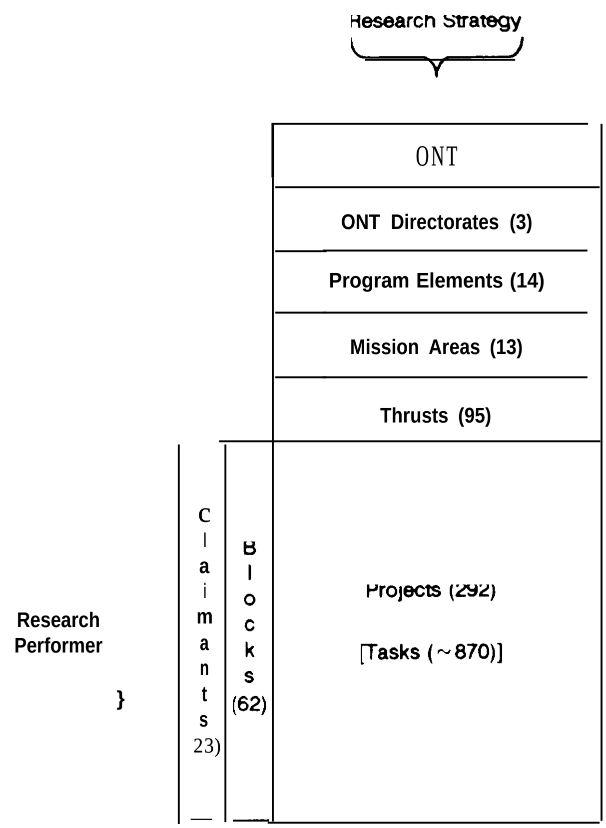
The entire 6.2 program is built around the Navy's 13 mission area strategies. ONT conducts an extensive top-down, bottom-up process to define its key mission area strategies. Since the six different Navy systems commands (SYSCOMS) are the ultimate users of the technology, they play an important role in the overall development of the Navy's exploratory development investment and mission area strategies. Besides the SYSCOMS and the laboratory/center technical directors, other inputs are sought from the Navy Secretariat, from the maritime strategy developed by OPNAV, from the CMC, and from internal and external scientific advisory groups.

The Navy develops a strategy for each of its 13 mission areas based on such concerns as current mission deficiencies, near-and far-term technological opportunities, the needs associated with DoD's overall maritime strategy, and potential military threats. According to ONT, a mission area strategy should be described where possible in terms of objectives that relate to a specific technology. For example, the Navy has broad mission strategies for antisurface ship warfare, anti-submarine warfare, and mine warfare. Because mission areas do not often change, the focus of this activity is on updating the strategy associated with each mission area.

In developing each mission area strategy, ONT establishes what it calls technology thrusts (see figures 6 and 7). According to ONT each technology thrust has a single operational/performance objective or several very closely related ones supporting the warfighting objectives of its mission area. ONT utilizes two definitions of technology to help identify a particular technological thrust:

- a science or engineering discipline specific to an application, such as:
  –laser communication technology,

Figure 6.–Navy 6.2 Program Structure



SOURCE: Office of Naval Technology

Figure 7.–Navy 6.2 Program Strategy

SOURCE: Office of Naval Technology

–fiber optic sensor technology, and
—optical signal processing; or

- a group of technologies applied to the same or closely related warfare, weapons, or platform objectives, such as:
  —ocean surveillance technology,
  —airborne electronic warfare,
  —air launch weaponry, and
  —torpedo propulsion.

In fiscal year 1987, the Navy supported its 95 technological thrust areas through the establishment of 62 block programs. A block program is an integrated group of technology projects with closely related applications and/or technical objectives; each block program is assigned to a given lead laboratory or SYSCOM program manager. For example, the Naval Air Development Center is responsible for a block program in airborne surveillance, while the SPAWAR SYSCOM is responsible for the block program in directed energy technology. Usually a block program encompasses the 6.2 program's effort (with an average funding level of $7 to 8 million) in a warfare technology area, as identified above. It is most often composed of a number of projects, each of which may address a different technology thrust and/or mission area. Each project consists of a number of specific tasks performed by a particular researcher or group of researchers.

Beginning in the fall of each year, all block programs are reviewed by ONT and the various SYSCOMS. This review is followed by an evaluation of the current mission area strategies, which leads to the establishment of new technological thrusts as well as new block programs for the following fiscal year.

ONT also sponsors an Independent Exploratory Development program, which provides the technical directors of the Navy R&D Centers with a small amount of funding (usually about 5 percent of their 6.2 programs) to support activities aimed at achieving the centers' assigned missions. Through this mechanism, the technical directors are allowed to support innovative programs without the formal approval process which could delay funding of a new idea. Normally, a specific program cannot be supported with Independent Exploratory Development funding for more than 3 years.

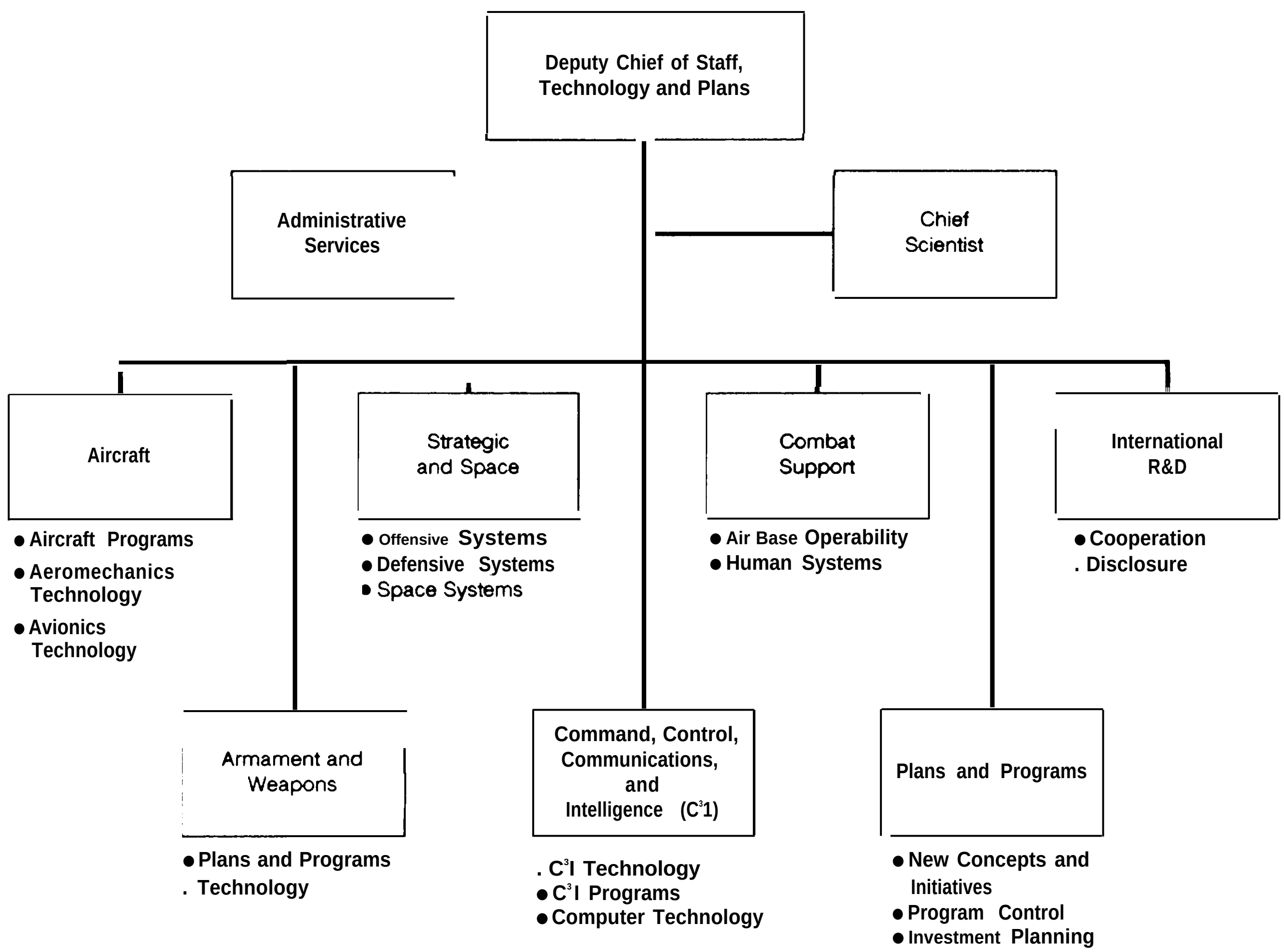
The Navy's advanced technology demonstration (6.3A) program, with a proposed fiscal year 1988 budget of about $30 million, is the smallest of the Services'. The Navy is the only Service that manages its 6.3A program separately from its 6.1 and 6.2 activities. Within the office of the Assistant Secretary of the Navy (Research, Systems, and Engineering), the Director of Research, Development, and Requirements (Test and Evaluation)—DRD&R(T&E)–has oversight responsibilities for the 6.3A program. The 6.3A program is managed by the Technology Assessment Office, which reports to the DRD&R(T&E). The Navy is now in the process of rebuilding its Advanced Technology Demonstration (ATD) program. In fiscal year 1988, the ATD program will sponsor three to five advanced technology demonstrations. The technologies are selected by the ATD director with the assistance of OPNAV, the SYSCOMS, and ONT, and are performed at the appropriate SYSCOM for up to 3 years.

THE DEPARTMENT OF THE AIR FORCE

The Deputy Chief of Staff for Technology and Plans- DCS(T&P)-of Air Force Systems Command (AFSC) is responsible for the daily operations and oversight of Air Force technology base programs (see figure 8). The DCS (T&P) reports to the Commander of the Air Force Systems Command, who reports to the Air Force Chief of Staff. The DCS(T&P) was created in October 1987 with the merger of the offices of DCS for Science and Technology with the DCS for Plans and Programs. The primary purpose of the merger was to enhance communication and coordination between the office responsible for evaluating and planning new weapon systems and the office that is responsible for conducting the research and advanced technology development for the new systems.

Within the office of the Secretary of the Air Force, the Assistant Secretary for Acquisition –ASAF(A)–is responsible for the entire Air Force's RDT&E program. And within the ASAF(A) office, the Director of Science and Technology (DS&T) is responsible for oversight of the Air Force technology base programs. The DCS(T&P) (in the headquarters of

Figure 8.–Air Force Systems Command R&D Organization



SOURCE Air Force Systems Command

AFSC) works with the DS&T (in the Office of the Secretary of the Air Force) in developing both an annual and a 5-year technology base investment strategy for the Air Force. One of the primary responsibilities of the DS&T is to ensure that the DCS(T&P) investment strategy is well balanced and capable of meeting the short- and long-term needs of the diverse Air Force technology users.

To help raise the visibility of its science and technology programs, the Air Force now treats its entire technology base program asa"corp~ rate investment. " Consequently, when budgets are being examined by the Air Force, the entire technology base program, rather than the 44 individual program elements, is examined for proper balance and emphasis. The goal is to raise technology base funding to 2 percent of the Air Force's total obligational authority. The technology base program is now classified as 1 of the 35 executive Air Force programs, equal in stature to such executive programs as the Advanced Tactical Fighter.

Management of the Air Force's Research (6.1) Program

The Air Force Office of Scientific Research (AFOSR) is responsible for the planning and management of the Defense Research Science program and the University Research Initiative program of the Air Force. The In-House Laboratory Independent Research Program (ILIR) is managed directly by each individual laboratory director. The Commander of the AFOSR reports to the Systems Command DCS(T&P), who has oversight responsibilities for AFOSR programs and for the integration of 6.1 research with 6.2 and 6.3A programs. AFOSR supports research which has a "potential relationship to an Air Force function or operation. " It conducts a program of extramural research contracts and grants (primarily grants); oversees the research programs (in-house and extramural) of the Air Force Laboratories; and manages three subordinate units.

The three subordinate units are the European Office of Aerospace Research and Development in London, AFOSR Far East in Tokyo, and the Frank J. Seiler Research Laboratory in Colorado Springs. The London and Tokyo offices gather information about foreign research and act as liaisons between Air Force scientists and engineers and their foreign counterparts. The Seiler Laboratory performs in-house research in such areas as optical physics, aerospace mechanics, fluid mechanics, and chemistry.

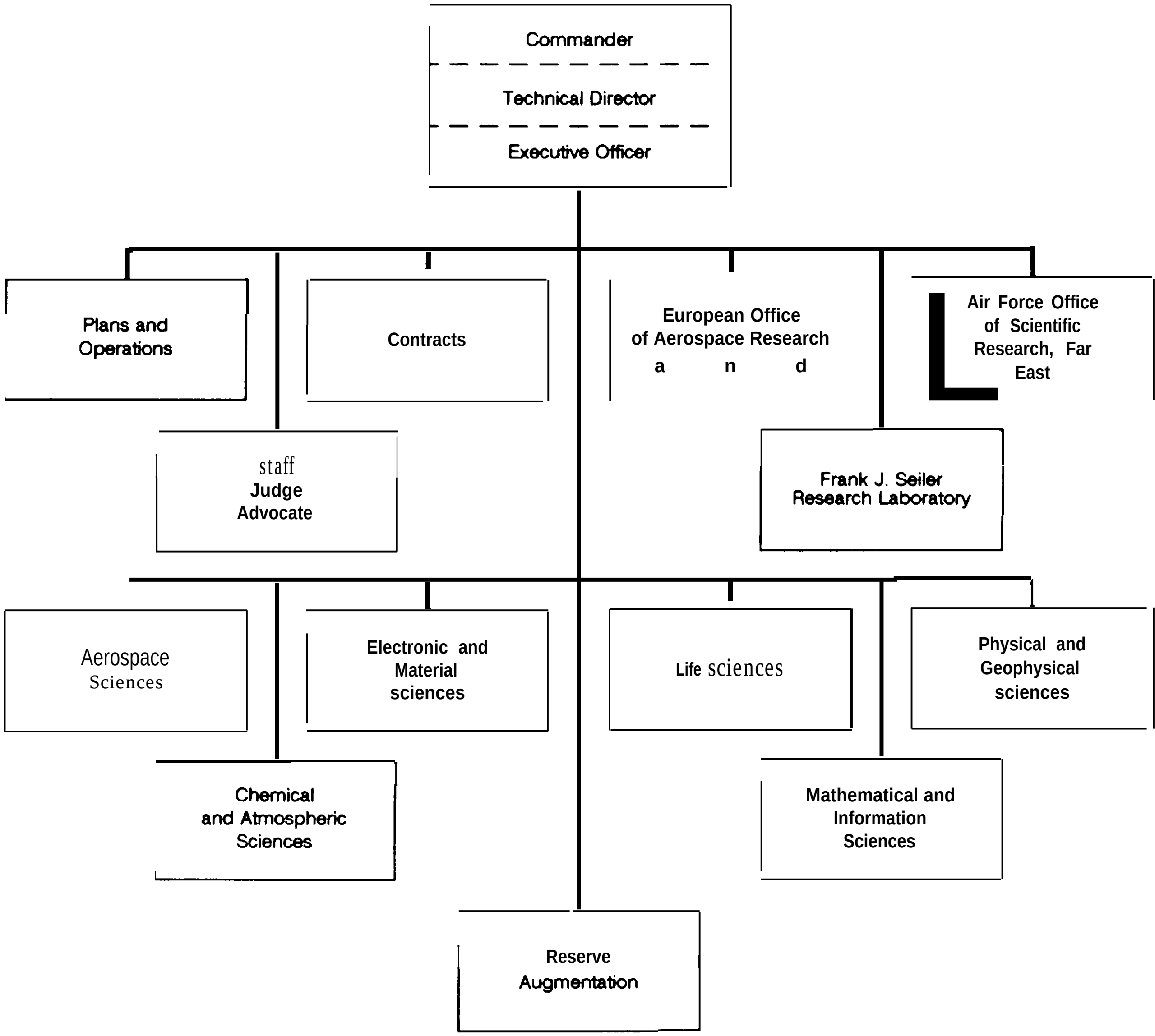
Of the $198 million the Air Force will spend on research in fiscal year 1988, about 60 percent will be given to colleges and universities. The Air Force in-house laboratories will receive 15 percent, industry and nonprofits 20 percent, and the remaining 5 percent is for overhead.

As figure 9 indicates, the AFOSR science programs are divided into six areas: Aerospace Sciences, Chemical and Atmospheric Sciences, Electronic and Material Sciences, Life Sciences, Mathematical and Information Sciences, and Physical and Geophysical Sciences. Each of the program areas has a scientific director, who is responsible (along with the Commander and Technical Director of AFOSR) for planning, managing, and implementing the various research programs. As might be expected, the majority of AFOSR research funds are spent in aerospace sciences, chemical and atmospheric sciences, and electronic and material sciences.

The AFOSR supports a number of special research programs to further strengthen the Air Force technology base program. They include the Air Force Thermionic Engineering Research Program, the Research in Aircraft Propulsion Technology Program, the University Resident Research Program, the Resident Research Associateship Program, the Laboratory Graduate Fellowship Program, the Advanced Composite Structures Program, the Graduate Student Summer Support Program, and the Summer Faculty Research Program.

In conjunction with industry, the AFOSR sponsors university-based manufacturing research centers at Stanford University and at the University of Michigan. Students perform

Figure 9.-Air Force Office of Scientific Research



SOURCE: Air Force Office of Scientific Research

research at the university centers or at participating companies. The Air Force provides the assistantship funds for M.S. and Ph.D. candidates, with Stanford and Michigan responsible for selecting the students. AFOSR funding for the two centers is scheduled to be phased out at the end of fiscal year 1988 as industry support increases.

Management of the Air Force's Exploratory and Advanced Technology Development Programs (6.2 and 6.3A)

The DCS(T&P) serves as the "corporate manager" of the Air Force's technology base program and is primarily responsible for developing the overall investment strategy that guides laboratory operations. The primary responsibility of the DCS(T&P) is to ensure proper integration and balance of these programs, while meeting the needs of the various operational commands, in line with OSD and Air Force Headquarters guidance. While having traditional oversight responsibilities for the 6.1 and 6.2 programs, the DS&T in the Air Force Secretariat exerts more active influence and direction on the large advanced technology development (ATD) program.

The office of the DCS(T&P), with approximately 70 professionals, consists of five major research directorates: Aircraft; Armament and Weapons; Strategic and Space; C^3I; and Combat Support. Each of the five Directorates works primarily with a particular AFSC product division and has oversight and coordination responsibilities for that division's lab(s). The Director of the Aircraft Directorate works with the four laboratory directors assigned to the Aeronautical Systems Division. The Armament and Weapons Directorate coordinates with the Armaments Laboratory of the Armament Division and the Weapons Laboratory of the Space Technology Center of Space Division. The Strategic and Space Directorate oversees the activities of the other two Space Division laboratories. The Director of C^3I is responsible for the research activities of the one laboratory assigned to Electronic Systems Division. Finally, the Combat Support Directorate works with the three laboratory directors of the Human Systems Division and the Air Force Engineering and Services Center.

However, this laboratory oversight arrangement does not mean that the director of a particular laboratory conducts research for only one of the five directorates. Obviously, the interdisciplinary nature of research requires the various laboratory directors to manage 6.2 and 6.3A activities for a number of product divisions and applications that cut across the major air commands.

Within the office of the DCS(T&P), the director of Plans and Programs works with the directors of the five research directorates to ensure their broad technology base investment strategy considers both the near- and long-term technological needs of the various Air Force users. The Plans and Programs office also works with the directorates to ensure that their respective technological thrusts are capable of meeting current and future needs of the Air Force.

Since 1980, the laboratories of the Air Force have been aligned under the parent product divisions: Electronics System Division (ESD), Armament Division (AD), Human Systems Division (HSD), Space Division (SD), and Aeronautical Systems Division (ASD). Each of the Divisions has responsibility for one or more laboratories which perform research, exploratory development, and advanced development in support of that division's mission as well as the missions of other divisions. For example, the Materials Laboratory, under ASD, meets the technology needs of Space Division as well. Unlike the other two Services, the Air Force laboratories are not full spectrum R&D laboratories. With the exception of the Rome Air Development center, which performs some 6.4 work, the remaining laboratories primarily conduct 6.1-6.3A activities. The Air Force supports the smallest in-house technology base program, actually conducting only 20 percent of its activities in its 14 laboratories. In contrast, the Air Force supports the largest 6.3A program, reflecting its interest in technology transition.

The directors of the laboratories have a dual reporting responsibility. The directors report their laboratory activities and accomplishments to both the DCS(T&P) as well as to the commander of their respective product divisions. (The four laboratory directors at Wright-Patterson Air Force Base report through the Commander of the Wright Aeronautical Laboratories to the Commander of ASD.) As with the other Services, each of the laboratory directors is ultimately responsible for the activities in his laboratory. This includes determining research priorities, developing new initiatives, determining who will be responsible for managing various research projects, whether to use in-house or outside expertise, and when to transition or stop a research activity.

The Air Force contends that placing its laboratories within the product divisions increases the linkages between the developers and ultimate users of the various weapon systems. The Air Force asserts that closer interaction between the product divisions and their respective laboratories will strengthen long-term technology base planning capabilities and the transition of mature technologies into systems applications. Further, the Air Force believes that this closer coupling will reduce the time it takes to develop and deploy more reliable and less expensive weapon systems.

The Air Force's advanced technology development (ATD) program has grown from $159 million in fiscal year 1975 to almost $754 million in fiscal year 1988 (see table 2). The ATD program represents 50 percent of the entire Air Force technology base program. Almost all of the ATD program is conducted by defense industries under contract to the different product division laboratories. The Air Force believes that its contractors will incorporate new technological advances more rapidly if they actually participate in the successful development and testing of a new technology.

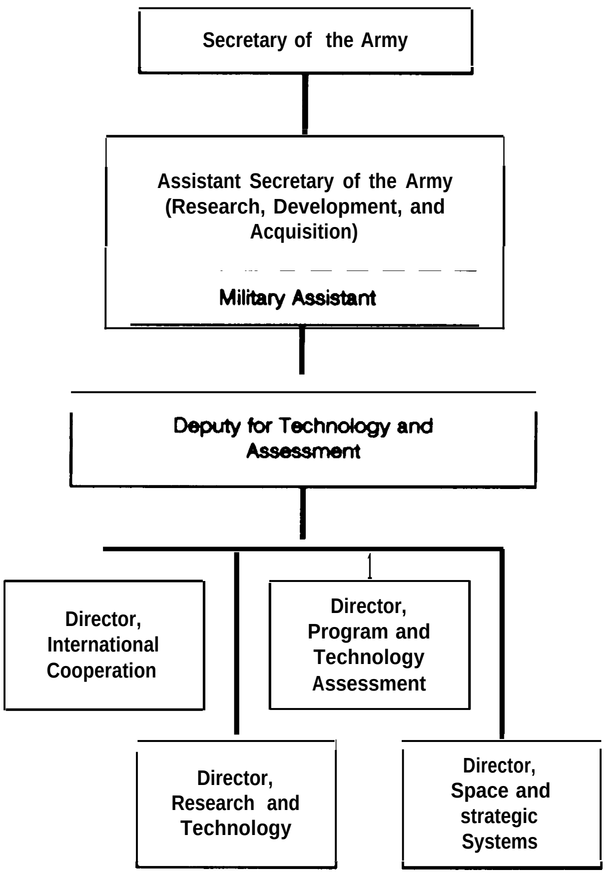
Like the other Services, the Air Force conducts an annual iterative planning activity. Much of the planning and programming activities at the Air Force laboratories are primarily driven by the future needs of the combat commands. This process begins in the second quarter of each fiscal year, when the DCS(T&P) develops an investment strategy to guide planning for the next 5 years. The results of this investment strategy, along with other guidance from DS&T, OSD, and inside and outside scientific advisory groups, are used to refine short-term plans and develop long-term plans by the laboratories. As part of their overall planning responsibilities, the product divisions identify a number of potential next generation system concepts to meet future warfighting needs. These warfighting requirements, in turn, are defined by the users.

The Air Force's Project Forecast II is another key consideration for developing an overall technology base strategy in the laboratories. Completed in 1986, the primary goal of Forecast II was to identify potential technological opportunities that could change the nature and design of future systems, while concomitantly improving the Air Force's warfighting capabilities. The Project was chartered by the Secretary of the Air Force and directed by the Commander of Air Force Systems Command (AFSC). It was supported by a team of 175 military and civilian experts drawn from within AFSC, the operational commands, and various outside advisory panels. From the ideas generated by the Air Force laboratories, industry, universities, and technology panels, 40 technological initiatives were identified for funding within the technology base. Research progress in these technological initiatives is monitored, and appropriate changes of emphasis are made as the technology matures. The purpose of this planning activity is to ensure that the Air Force technology base program is sufficiently broad to prevent technological surprise by potential adversaries, while at the same time is in position to take advantage of new technological opportunities.

THE DEPARTMENT OF THE ARMY

The newly created office of the Deputy for Technology and Assessment (DT&A) is responsible for the Department of Army's entire technology base program. The DT&A reports to the Assistant Secretary of the Army for Research, Development, and Acquisition—ASA(RD&A)–who replaced the Deputy Chief of Staff for Research, Development, and Acquisition—DCS(RD&A) —(see figure 10). The Army has combined both military and civilian oversight responsibilities for its RDT&E program in one office.

Figure 10. -Army Research and Development Organization



SOURCE: Assistant Secretary of the Army (Research, Development, and Acquisition).

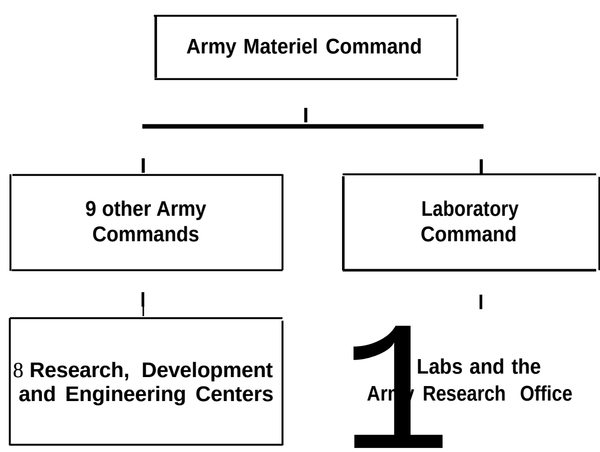
As a result of the Goldwater-Nichols Act, the Army has also designated the DT&A as its Program Executive Officer (PEO) for the technology base programs. The DT&A provides programmatic planning guidance to the Army's 31 Research and Development organizations. DOD's planning guidance is used by the Army to help develop its annual and 5-year technology base Program Objective Memorandum (POM).

Subordinate to the DT&A is the office of the Director of Research and Technology (DR&T, see figure 10), which is responsible for planning and coordinating the Army's entire technology base program. The remaining three offices under DT&A, the Director of International Cooperation, the Director of Program and Technology Assessment, and the Director of Space and Strategic Systems, work with the DR&T on various special aspects of the technology base program. Since this is a completely new organization, the exact responsibilities of these offices have yet to be determined.

The Army operates its technology base programs differently from the other Services and tends to have a more complicated organizational structure. The Army divides its technology base programs among four major components: the Army Materiel Command (AMC), the Surgeon General of the Army (TSG), the Corps of Engineers (COE), and the Deputy Chief of Staff for Personnel (DCSPER). For oversight purposes, the directors of all four of these organizations report to the Deputy for Technology and Assessment at Army headquarters.

AMC is responsible for the development and acquisition of all the Army's combat and combat support systems (see figure 11). AMC receives 75 percent of the Army's technology base funding and is programmatically responsible for eight research, development, and engineering (RDE) centers, seven army laboratories, the technology base work of the project

Figure 11.-Army Materiel Command R&D Organization



SOURCE: Army Materiel Command

manager for training devices, and the Army Research Office. The Surgeon General manages 14 percent of the technology base programs and is responsible for medical R&D activities at the Army's nine medical laboratories. The Corps of Engineers operates four laboratories and utilizes 6 percent of the technology base funding to support research in such areas as construction engineering, cold weather combat, and hydrology. The Army Research Institute for Behavioral and Social Sciences (ARI), which reports to the DCSPER, receives about 1 percent of the technology base funding for research in personnel-related areas. The remaining 4 percent is for overhead and the ILIR program. However, due to budgetary constraints the Army did not propose any funding for ILIR in fiscal year 1988.

Management of the Army's Research (6.1) Program

The Army is the only Service that manages its basic research program through more than one office. The majority of the 6.1 program is managed by the Army Research Office (ARO), located at Research Triangle Park in North Carolina. ARO is under the Army's Laboratory Command (LABCOM) structure, with the Director of ARO reporting to the DT&A through LABCOM and AMC. Compared to equivalent organizations in the other Services' research offices, ARO is lower in the chain of command and appears to have less visibility. In fiscal year 1988, AMC will receive a little over two-thirds of the Army's 6.1 budget. Half of AMC's 6.1 funding will go to the ARO and the other half will go to the AMC laboratories and RDE centers. Although ARO does not manage the portion that goes to the Army laboratories and centers, it does make recommendations to the Director for Research and Technology, Army Headquarters, regarding the in-house research program content and size.

The ARO program is a mix of short- and long-term programs that are responsive to the needs of the Army laboratories. Recently, ARO has worked closely with the Army Training and Doctrine Command (TRADOC) and its schools to assist in shaping ARO's research program according to Army mission area needs. TRADOC, along with AMC, is responsible for evaluating the current and future technological needs of the Army.

The ARO provides the major interface between the Army and the university community. The university community receives 83 percent of ARO's 6.1 budget; industry gets 10 percent and nonprofit organizations *receive* the remaining 7 percent. The ARO research program consists of seven divisions: Electronics, Physics, Chemistry and Biology, Engineering, Material Science, Mathematics, and Geosciences.

The laboratories' in-house research programs are organized along the lines of the laboratories' mission responsibilities. For example, each laboratory research effort is supported by a single project fund (SPF) more closely tied to its mission, rather than to some specific scientific discipline. The content of each SPF is determined by each laboratory's technical director and his staff. Research in the laboratory is really designed to be the first step in the development chain. ARO contends that research tasks within an SPF are intended to lead eventually into development programs. The technical content of each SPF is reviewed annually by each Command headquarters and by the Deputy for Technology and Assessment (DT&A).

Since 1982, ARO has sponsored a "centers of excellence" program, supporting selected colleges and universities. ARO operates centers in five research areas: electronics, mathematics, rotary wing aircraft technology, artificial intelligence, and optics. These centers are usually funded from 5 to 10 years. Each center has a program advisory panel with members from the different universities, ARO, the appropriate laboratory within AMC, and industry. For example, the Army Aviation Systems Command Research Development and Engineering Center works with three universities that are the Army's rotocraft centers of excellence.

Army's Management of Exploratory and Advanced Technology Development Programs (6.2 and 6.3A)

The Director for Research and Technology (DR&T) is also responsible for the exploratory and advanced technology development programs of the Army. There are four Deputy Assistant Directors that have specific responsibilities for various aspects of the Army's science and technology programs. These four areas are: 1) aviation—unmanned air vehicles and missiles, etc.; 2) ballistics-sighting mechanisms, armaments, munitions, chemical warfare, etc.; 3) electronics-artificial intelligence, command, control, communications, and intelligence, robotics, etc.; and 4) soldier support–ground combat, troop support, and ground vehicles.

Within the office of the DR&T there are five science and technology professionals (the Director and the four Deputy Assistant Directors) responsible for planning, budgeting, and setting priorities for the Army's technology base programs. Consequently, the Army utilizes a much more decentralized management approach in operating its laboratories than do the other Services. Although the DT&A has primary oversight for planning, budgeting, and setting priorities, many of these activities are directed and performed by the Army Material Command (AMC) office and the newly created Laboratory Command (LABCOM) (see figure 11).

The Army's LABCOM has only been in existence for a little over 2 years. According to Army officials, the long-term goal of AMC is to have ARO and the seven laboratories under LABCOM primarily responsible for generic technology base work, while the eight Research, Development, and Engineering Centers would be primarily responsible for engineering and development activities that are more systems related. The goal is to have the laboratories "hand-off" certain technology base programs to the RD&E centers to initiate appropriate systems engineering and development activities.

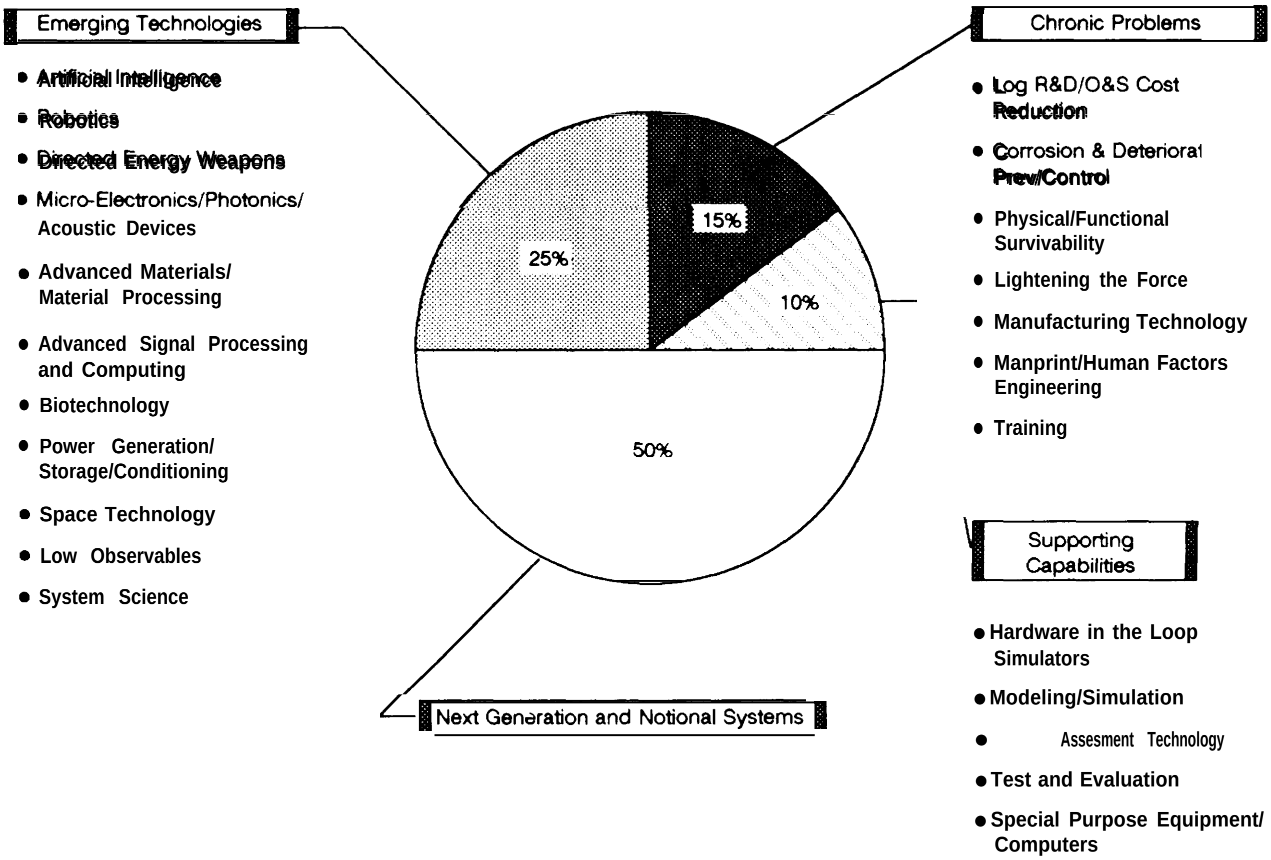
In 1986 LABCOM published its first comprehensive technology base investment strategy. According to the Army, the purpose of the investment strategy is to meet future user battlefield requirements while preserving the Army's ability to exploit technological opportunities. The investment strategy is also used to determine resource allocation for technology base activities, and it provides a strategic vehicle for articulating the direction of the AMC technology base activities. The AMC breaks its strategy into four basic elements (see figure 12): next generation and notional systems (NGNS); emerging technologies (ET); chronic problems; and supporting analytical capabilities.

Nearly half of the AMC's technology base resources are planned for next generation/notional systems. Next generation systems are usually defined as those beyond the systems currently in engineering development; they represent relatively well-defined solutions to battlefield problems of the next 5 years. Notional systems, on the other hand, are more conceptual solutions to problems anticipated 10 to 15 years down the line. This distinction provides a range of targets for technology base efforts, from mid-range to long term.

As figure 12 indicates, emerging technologies support 25 percent of the technology base strategy. These are technologies such as robotics, artificial intelligence, and biotechnology which may not yet have coalesced into spe cific systems applications. The Army admits that the difference between ETs and NGNS is "fuzzy;" nevertheless, ETs are judged to be so important that they deserve special emphasis through visibility and funding emphasis. Most of the ET activities are focused on exploring new technological concepts that could be used by the Army 15 to 30 years in the future.

Certain chronic problems, such as corrosion prevention and manufacturing problems, are endemic to the ability of the Army to perform its mission but often do not receive technology base support. Although these may be less

Figure 12.-Army Technology Base Investment Strategy



SOURCE: Army Materiel Command/Laboratory Command

glamorous than developing new weapon systems, 15 percent of the technology base support is now devoted to these concerns.

Supporting analytical capabilities include modeling, simulation, advanced demonstration projects (ADP), and other infrastructure activities aimed at increasing the Army's ability to perform quality R&D and improve its acquisition across the entire spectrum of the material life-cycle. This category, representing the remaining 10 percent of technology base funding, is devoted to future operational capabilities and improving the research infrastructure.

The Army asserts that the AMC laboratories and the RD&E centers, ARO, and to a lesser extent the Corps of Engineers' laboratories are required to formulate their technology base strategies within this investment strategy framework. However, this does not necessarily mean that every lab or center must be working on every element of the strategy, or that its budget must reflect the exact percentage allocation for each element. Nevertheless it does mean that:

> ••• each organization should plan their technology base work to address (within their mission area) the technological barriers represented by the specific set of NGNS, and that they should give emphasis to the other elements of the strategy before pursuing other work, which may nevertheless be important in its own right.[21]

“A *LABCOM White Paper* ''The AMC Technology Base Investment Strategy, ” June 7, 1987, p. 43.

The technology base investment strategy is developed through an annual analysis of the Army's 13 major mission areas (e.g., close combat (light), close combat (heavy), air defense, mine/counter-mine, etc.). The mission area analyses, which are conducted by TRADOC with support from AMC, COE, TSG, and ARI, result in the publication of a Battlefield Development Plan that outlines both near- and mid-term battlefield deficiencies and opportunities. Directed by AMC, the Army then conducts what is called a mission area materials process (MAMP) to address the various deficiencies and opportunities in the context of the four elements of the mission area strategy.

The technology base investment strategy and the MAMP drive the technology base activities in several ways. They are used as strategic planning tools, laying out the projected development time schedules of the systems planned for the future. Further, both TRADOC and AMC review the 13 mission area strategies for duplication and opportunities for collaborative efforts among the labs and centers to help meet deadlines and reduce technology base costs.

Since the next generation and notional systems are intended to focus on near- and long-term technological barriers, a large percentage of the 6.2 and 6.3A budget is spent in this area. For example, almost all of the 6.3A budget is spent on approximately 60 specific technology demonstrations. Each year the Army publishes a document that describes the "Top-20' demonstrations and identifies the laboratory responsible for managing the demonstration. Each demonstration can last from 3 to 5 years.

Like the other Services, the Army performs an annual top-down, bottom-up guidance and direction exercise. This evaluation begins in the fall when each lab and center presents a review of its accomplishments, along with plans for meeting next year's technology base strategy. The Army utilizes a Technology Base Advisory Group to set project priorities. This group works with representatives from TRADOC and the Department of the Army headquarters in establishing the overall project priorities for the technology base investment strategy.

THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)

At just under $800 million in fiscal year 1988, the technology base program of the Defense Advanced Research Project Agency (DARPA) is larger than those of the other defense agencies combined. The other agencies are: the Defense Nuclear Agency (DNA); the Defense Communications Agency (DCA); the National Security Agency (NSA); and the Defense Mapping Agency (DMA). DARPA was established in 1958 partly due to the pressures forced by the launching of the Sputnik satellites. The President and Congress also recognized that DoD needed an organization which could take the "long view" regarding the development of high-risk technology. DARPA was thus setup to be DoD's "corporate" research organization, reporting to the highest level (currently the USD(A)) and capable of working at the "cutting edge" of technology. DARPA's organization allows it to explore innovative applications of new technologies where the risk and payoff are both high, but where success may provide new military options or applications—or revise traditional roles and missions. In theory, since DARPA has no operational military missions, it should be able to maintain objectivity in pursuit of research ideas which promise quantum technology advancement.

DARPA executes its programs mainly through contracts with industry, universities, nonprofit organizations, and government laboratories. DARPA now has a limited inhouse contracting capability. This means that DARPA can contract directly with defense contractors, rather than going through the

Services. However, the Services and other government agencies usually provide this function. In these cases, technical monitoring and support are often provided as well, thus establishing a "joint program atmosphere. According to DARPA, close relationships with the Services facilitate subsequent technology transfer when research projects reach a mature stage and are linked to operational requirements.

Organization

The DARPA organization is tailored for the agency's role and is often "adjusted" to accommodate priorities. DARPA consists of the Director's office (including the new Prototype Office and two Special Assistants-one for Strategic Computing and one for the National Aerospace Plane), two administrative support offices, and the following eight technical offices:

1. Tactical Technology Office,
2. Strategic Technology Office,
3. Defense Sciences Office,
4. Information Science and Technology Office,
5. Aerospace Technology Office,
6. Naval Technology Office,
7. Directed Energy Office; and
8. Technical Assessment and Long-Range Planning Office.

DARPA's programs are divided into two broad categories: Basic Technology Projects and Major Demonstration Projects. The Basic Technology Projects focus on long-term research in the areas that are related to a specific technical office. As some of these technology investigations begin to show promise, feasibility demonstrations are conducted, often in cooperation with the military Services, in an attempt to transfer the technology as rapidly as possible into system development—thus matching technology with requirements.

The Prototyping Office was established this past year in response to a recommendation of the Packard Commission on Defense Acquisition. Prototype projects will consist of "brass-board" models, feasibility demonstrations, and experimental vehicles. Some concerns have been expressed that this new responsibility, if improperly managed, could jeopardize DARPA's basic charter-that of examining high-risk technologies, proving feasibility, and quantifying risk without the pressures for demonstrating military applications. It is too early to tell if this concern is justified.

Programs and Priorities

DARPA's scope of programs and responsibilities is broad and appears to be growing as more joint programs are being added to DARPA's overall responsibilities. Among the key projects underway are the X-29 Advanced Technology Demonstrator, being conducted in conjunction with NASA Ames Research Center; the X-Wing Demonstrator; Advanced Cruise Missile Technology; Particle Beam Technology; Strategic Computing; and a high-priority effort to examine technology for armor/anti-armor. DARPA also has a growing materials program investigating advanced composites, other complex materials, and electronic materials including gallium arsenide.

THE STRATEGIC DEFENSE INITIATIVE ORGANIZATION

Headed by a Director who reports directly to the Secretary of Defense, the Strategic Defense Initiative Organization (SDIO) is a centrally managed defense agency with both technical and administrative offices. The offices address ongoing scientific research, broad policy issues, and overall funding issues. There are five technical program directorates (Surveillance, Acquisition, Tracking, and Kill Assessment; Directed Energy Weapons; Kinetic Energy Weapons; Systems Analysis and Battle Management; and Survivability, Lethality and Key Technologies) and a program manager for Innovative Science and Technology. Although the entire SDI program is funded under the Advanced Technology Development category (6.3A), much of the work supported by the Innovative Science and Technology office could be classed as generic research or exploratory in nature.

As with the "traditional" S&T program, spe cific SDI projects are executed primarily through the Services (Army, Navy, and Air Force), with some additional efforts through other executive agents including DARPA, DNA, the Department of Energy, and the National Aeronautics and Space Administration.

SUMMARY

The Department of Defense will invest almost $9 billion in technology base activities in fiscal year 1988. DOD's complex technology base program is planned, organized, and implemented by DARPA, SDIO, and the three Services, with oversight and guidance provided by the Office of the Secretary of Defense (OSD). The majority of the technology base program is conducted by industry (50 percent), with universities performing 20 percent and the DOD in-house laboratories conducting the remaining 30 percent. The primary goal of the technology base program is to counter Soviet numerical manpower and weapons superiority through the development of superior technology for future weapons systems. Thus, DOD contends a growing technology base program is critical to the successful execution of the Nation's defense policies.

Within the last 3 years, each of the three Services and the OSD have reorganized their technology base programs. As a result of the Goldwater-Nichols Act, the USD(A) was established and given responsibility for all RDT&E activities except for those of the Director of SDIO, who reports directly to the Secretary of Defense. The Goldwater-Nichols Act also reestablished the Director of Defense Research and Engineering (DDR&E) as the primary spokesman for DOD's technology base activities.

Within OSD, the DDR&E is primarily responsible for providing an overall corporate emphasis and balance for DOD's entire technology base program, except for SDI. Once the Services have formulated their technology base programs, the primary role of the DUSD (R&AT) is to ensure that their proposals have responded to OSD guidance. The Deputy for R&AT must also be sure that the Services' programs are well balanced, do not duplicate effort, and attempt to meet the current and future technological needs of DOD.

Each of the three Services operates and manages its technology base activities differently. The Army uses a more decentralized approach in managing its technology base programs; it relies its major field commands-AMC headquarters, the Corps of Engineers, the Surgeon General, and the DCS for Personnel–to help develop and implement its technology base investment strategy. This is primarily due to the small size of the Army's technology base headquarters staff. The Deputy for Technology and Assessment (DT&A) is considered to be the Army's Program Executive Officer (PEO) for the technology base programs. The DT&A is responsible for coordinating technology base programs of AMC, the Surgeon General, the Corps of Engineers, and the DCS for Personnel. AMC headquarters is responsible for oversight and management of the Army's eight laboratories, seven RD&E Centers, the project management training device, and the Army Research Office.

Unlike the other Services, the Navy, which recently reorganized its laboratory organization, performs the majority (60 percent) of its technology base programs in-house. Many of the Navy laboratories are considered to be full spectrum labs, capable of performing the entire range of RDT&E activities. The Navy's basic research program is the oldest and largest of the Services, whereas its advanced technology demonstration program is the smallest. The Navy contends it is in the process of rebuilding its advanced technology development program, which, unlike the other Services, is not managed in the same office as its 6.1 and 6.2 programs.

As of November 1, 1987, the Deputy Chief of Staff for Technology and Plans was established to oversee the Air Force technology base programs. The DCS(T&P) is also the PEO for, and the single manager of, the Air Force technology base program. The Air Force Chief of Staff has recently designated the technology base program as a "corporate investment" to help raise its visibility and to provide a long-term stable funding base. The Air Force operates the largest extramural technology base program. Its technology base activities are more centralized than those of the other Services. The Air Force laboratories are more closely linked to product divisions than are those of the other Services, and this linkage influences the types of 6.2 and 6.3A activities each laboratory performs.

The role of DARPA appears to be changing with the recent establishment of the Prototyping Office. There is some concern that this might compromise DARPA's support of high-risk technologies (only 11 percent of DARPA's budget is for research), as well as its role of proving feasibility and quantifying risk without the pressure for demonstrating military application. The majority of DARPA's budget is contracted through the three Services to industry (75 to 80 percent) and universities (20 percent), with only a small fraction of DARPA's technology base activities actually conducted by the military.

The SD I program is centrally managed with its director reporting to the Secretary of Defense. Less than 5 percent of the SDI budget is spent on basic research, with the remainder divided between exploratory development and advanced technology development. The majority of SDI projects are executed through the Services, with some additional efforts through other executive agents including DARPA, DNA, the Department of Energy, and the National Aeronautics and Space Administration.