Chapter 4

Planning and Funding DoD Technology Base Programs

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INTRODUCTION

In today's technology-intensive environment-in both the military and commercial context—the ability of an organization to compete and win is highly dependent on its ability to discover, develop, and apply advances in science and technology to its systems and products. Success in that endeavor depends, in turn, on the ability of the organization to plan its technology investment strategy, marshal the resources to support it, and build and sustain a technology base vital enough to produce the needed advances.

The development and management of the technology base underlying defense systems is an exceedingly complex enterprise. It is as multifarious—and as important to national interests—as the capabilities and performance of the defense systems themselves. This chapter examines the Department of Defense (DoD) system for managing its technology base programs. It reviews how the Office of the Secretary of Defense (OSD)-particularly the Office of the Director of Defense Research and Engineering (ODDR&E)--carries out its technology base oversight responsibilities. The purpose of this chapter is to evaluate the ability of the present OSD technology base management system to do its job, and not to judge the performance of any Administration or individual DoD officers. It focuses on oversight activities such as strategic planning and coordination of technology base programs-that is, on the role of OSD in planning the programs of the Services, defense agencies, and the Strategic Defense Initiative Organization (SDIO), and forming them into a coherent whole—and not on the management of specific technology base program elements (PEs).

These oversight responsibilities include: 1) developing an overall technology base investment strategy; 2) setting research priorities and directions; 3) reviewing and evaluating the technology base program goals; 4) coordinating the numerous research activities that make up DoD's technology base programs; 5) acting as an advocate for the technology base programs; and 6) evaluating the outcomes and effectiveness of DoD-sponsored technology base activities.

The next section of this chapter briefly describes the activities that comprise DoD's technology base programs and how OSD, the three Services, the Defense Advanced Research Projects Agency (DARPA), and the SDIO[2] are organized to manage and implement their technology base programs. The following section then reviews how OSD, the three Services, and DARPA fulfill their respective technology base management responsibilities.

The second major portion of the chapter examines issues associated with the way in which OSD is organized to carry out its technology base oversight activities. The chapter concludes with a discussion of the support within DoD for its technology base programs, including an analysis of past and current technology base funding trends.

HOW THE DEFENSE DEPARTMENT MAKES AND IMPLEMENTS TECHNOLOGY POLICY

Although the Department of Defense will invest less than 4 percent of its entire budget in technology base activities in fiscal year 1989 (see table 1), many observers inside and outside the Pentagon consider DoD's technology base programs to be a crucial investment in the Nation's overall security. The military's technology base programs represent a wide spectrum of "front-end" technology development, beginning with a broad base of basic research support and extending through the demonstration of technology that might be applied in future defense systems. The scope of DoD's technology base

[1] For a more detailed discussion of how OSD and the Services organize their respective technology base programs, see the March 1988 OTA report entitled *The Defense Technology Base. Introduction and Overview—A Special Report,* OTA-ISC-374 (Washington, DC: U.S. Government Printing office).

[2] For further information on the SDI program, see Library of Congress, Congressional Research Service, "The Strategic Defense Initiative: Program Description and Major Issues," CRS Report No. 86-8 SPR, 1986.

Table l—Department of Defense Funding of Technology Base Programs, Fiscal Year 1989
(in millions of dollars)[a]

	Army	Navy	Air Force	DARPA	Category
Research (6.1)	$173	$355	$196	$88	$956
Exploratory Development (6.2)	$561	$431	$574	$624	$2,522
Advanced Exploratory Development (6.3A)	$422	$193	$764	$557	$2,099
Service or agency total	$1,156	$979	$1,534	$1,269	$5,577
Strategic Defense Initiative					$3,606
Total DoD technology base programs					$9,183

appropriated,
[b]Category totals also include funding for the other defense agencies and University Research Initiatives program.

SOURCE: Office of the Secretary of Defense.

programs includes such diverse concerns as meteorology technology and the technologies for autonomous guided missiles capable of differentiating among various targets.

DoD organizes its technology base programs into three budgetary categories: research (funded under category 6.1); exploratory development, the practical application of that research (budget category 6.2); and advanced exploratory development, which primarily consists of the building of prototypes to demonstrate the feasibility of applying a particular technology to a weapon system (budget category 6.3A). Work funded under the remainder of the Department's budget for research, development, test, and evaluation (RDT&E), representing about 80 percent of the RDT&E budget, is not considered to be part of the technology base.[3]

DoD's complex technology base program is planned, organized, and implemented by the three Services (Army, Navy, and Air Force), DARPA, the other defense agencies, and the SDIO, with the oversight and guidance of the OSD. The largest portion of the technology base program is conducted outside DoD by industry (50 percent) and universities (20 percent), with DoD in-house laboratories conducting the remaining 30 percent.

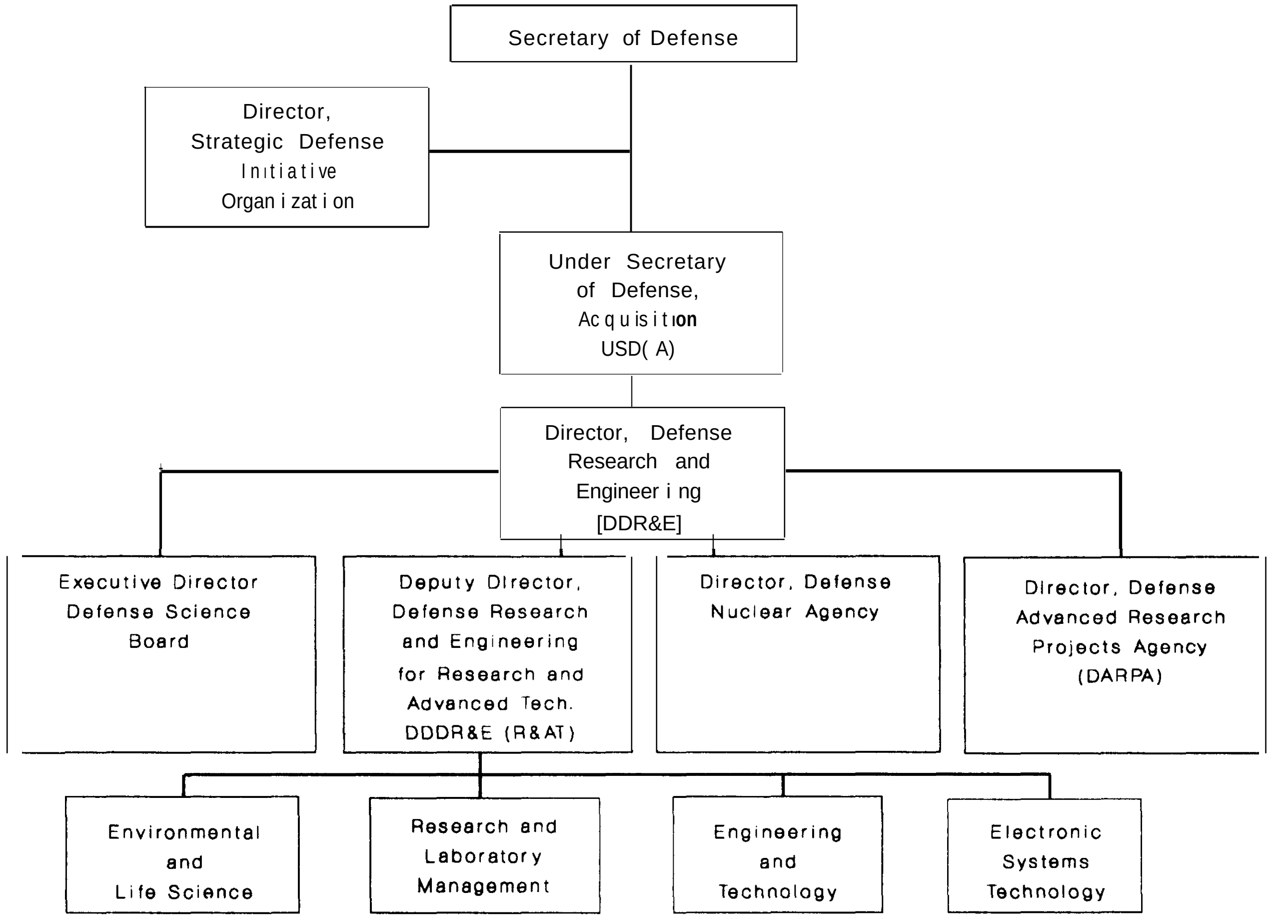
In the last three years, each of the three Services and OSD have reorganized the management of their technology base programs. As a result of the Goldwater-Nichols Act, the position of Under Secretary of Defense for Acquisition [USD(A)] was established and given responsibilities for all RDT&E activities except for those of the SDIO. The Director of SDIO reports directly to the Secretary of Defense (see figure 2). The Goldwater-Nichols Act also reestablished the DDR&E as the primary individual responsible for DoD's technology base activities. The DDR&E is responsible for assuring the appropriate emphasis and balance for DoD's entire technology base program, except for SDIO.

Once the Services-the Army, Navy, and Air Force—have formulated their technology base programs, the Deputy DDR&E for Research and Advanced Technology [DDDR&E(R&AT)] has the task of ensuring that their proposals have responded to OSD guidance. The Deputy for R&AT serves as ''the corporate guardian" of the technology base programs, ensuring that the Services' programs are well balanced, with little duplication of effort, while attempting to meet the current and future scientific and technological needs of DoD. The Services' technology base programs are coordinated with DARPA's programs at the next level, the DDR&E. Finally, conflicts among these four programs and SDIO are adjudicated only at the highest level, the Secretary of Defense.

Each of the Services conducts an extensive annual top-down, bottom-up planning exercise. From the top, the Services receive OSD's annual Defense Guidance document, which provides them with guidance on developing their overall RDT&E programs. Planning begins with a review and

[3]DoD typically 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. " However, in recent years these distinctions have become blurred in everyday usage. This report uses both terms to refer to budget categories 6.1, 6.2, and 6.3A.

Figure 2—Management of the Department of Defense Technology Base Program



SOURCE: Office of Technology Assessment, 1989.

evaluation of the previous year's research activities. When this review is completed, the Services then decide which activities to continue, which to transition from 6.1 into 6.2 or from 6.2 into 6.3A programs, which to move beyond 6.3A, and which activities to end.[4]

Each of the three Services operates and manages its technology base activities differently. Compared to the other two, the Army employs a less centralized approach, relying on major field commands-the Army Materiel Command (AMC), the Corps of Engineers (COE), and the Surgeon General (TSG)—as well as the Deputy Chief of Staff for Personnel (DCSPER), to help develop and implement its technology base investment strategy. Compared to those of the Navy and Air Force, the Army's technology base headquarters staff is quite small. 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 the technology base programs of AMC, COE, TSG, and the DCS for Personnel. The Army's Laboratory

[4] Transitions may actually occur at times from 6.1 or 6.2 to 6.3, 6.4 Or even directly to operational systems.

Command (LABCOM) is responsible for overseeing and managing 75 percent of the Army's technology base program, including its eight laboratories, seven research, development, and evaluation (RD&E) centers, and the Army Research Office. The commanding officer of LABCOM reports to the commander of AMC.

Of the three Services, the Navy has placed its technology base management institutions at the farthest remove from its procurement institutions. But relevance to Navy needs still remains a powerful factor in selecting projects, especially in 6.2 and 6.3A. Further, unlike the other Services, the Navy performs the majority (60 percent) of its technology base programs in-house. Many of the Navy laboratories are capable of performing the entire spectrum of RDT&E activities. The Navy supports the oldest and largest of the Services' research programs, along with the smallest program in advanced technology demonstration. The Navy claims to be rebuilding its advanced exploratory development program, which, unlike the other Services, it does not manage 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 (DCS T&P), Air Force Systems Command, was established to oversee the entire Air Force technology base program. The DCS T&P is also the PEO for, and the single manager of, the Air Force's technology base program. The Air Force Chief of Staff has designated the technology base program as a' 'corporate investment" to help raise its visibility and to provide a long-term, stable funding base for the program. The Air Force operates the largest extramural technology base program of the three Services. Its technology base activities are more centralized than are those of the other Services. The Air Force places special emphasis on technology insertion: It has the largest advanced exploratory development program; and its laboratories are more closely linked to its five major systems divisions than those of the other Services are to theirs.

The role of DARPA appears to be changing with the recent establishment of its Prototyping Office, DARPA was originally established to support high-risk, long-range research. It does not operate laboratories or conduct in-house research. Consequently, 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. There is some concern that allowing DARPA to enter the domain of hardware development and prototype testing might compromise its support of long-range, high-risk research.

The SDIO program is centrally managed, with its director reporting to the Secretary of Defense. Although the entire SDIO budget is funded under 6.3A, DoD estimates that approximately 15 to 20 percent of the SDI budget is spent on research and exploratory development. The majority of SDI projects are executed through the Services with some additional efforts through other executive agencies, including DARPA, the Defense Nuclear Agency, the Department of Energy, and the National Aeronautics and Space Administration.[5]

OSD'S TECHNOLOGY BASE OVERSIGHT ACTIVITIES

The DoD technology base programs play a crucial role in the military's ability to develop technology and apply it rapidly to meeting the Nation's security needs. DoD reports that its science and technology capabilities continue to improve, but the technological lead over potential adversaries is shrinking. One way for DoD to counter this adverse trend is to make sure that its technology base programs are planned, managed, and executed as effectively as possible.

Developing a Technology Base Investment Strategy

DoD does not have an overall, coordinated technology base investment strategy or plan to establish science and technology (S&T) priorities. According to a recent report by the Institute for

[5]This chapter does not examine the research activities of several smaller agencies within DoD which account for less than 2 percent of RDT&E. Those agencies include: the Defense Mapping Agency; National Security Agency; Defense Nuclear Agency; Defense Support Project Office; Defense Communications Agency; Defense Intelligence Agency; Defense Logistics Agency; and the Uniformed Services University.

Defense Analyses (IDA),[6] a significant amount of long-range planning is taking place in the Services, the research and development (R&D) centers, and DARPA, but "these efforts are, at the moment, pursued independently within each of the Services and, to some degree, independently at the R&D center (laboratory) level."[7]

Many observers within the military believe that technology base planning should remain decentralized.[8] The Services assert that they have a much better understanding of their respective combat needs than does OSD. As a result, the Services-not OSD-possess the knowledge and technical skills necessary to establish a rational technology base investment strategy to meet future combat needs. Many analysts believe that any attempt to centralize planning for the technology base programs within USD(A) would be unsuccessful. Representatives of the Services and DARPA argue that OSD's primary role should be as advocate, reviewer, and coordinator for DoD's technology base programs, In this view, USD(A) should make sure that the technology base is clearly understood within OSD, that Service and DARPA programs are reviewed for adequacy, and that unwarranted program duplication between the Services is avoided. Advocates of this view also hold that OSD is less able to defend the technology base budget than are the Services, and greater OSD involvement would result in less Service support of the technology base.

On the other hand, the report of the IDA task force does not endorse these beliefs. The task force recommended that OSD adopt a strategic planning process to "tie together the investment strategies as they currently exist in the Services and Agencies. "[9] This strategic planning activity would involve OSD working *with* the Services, the defense agencies, and SDIO in order to establish technology base goals and priorities. It does not imply the creation of an OSD "planning czar" who establishes goals and objectives for all of DoD's technology base programs. The IDA report notes that strategic planning, in any organization, will not succeed if it fails to involve an adequate number of the right people. In this approach, once a coordinated technology base investment strategy has been developed, the actual planning and execution of the various programs could continue in the current decentralized fashion, As in the past, the Services and DARPA would be responsible for organizing and executing their technology base programs. However, the DDR&E would be in a position to evaluate each agency's program, based on how well it responded to the priorities established during the strategic planning process.

The Services and DARPA assert that the annual Defense Guidance document-supplemented with additional Service requirements documentation-provides adequate planning guidance to develop their respective technology base investment strategies. However, many other observers criticize the Defense Guidance on the ground that it is developed through a fragmented process which fails to produce a coherent, well-coordinated U.S. defense posture. The document is prepared by the UnderSecretary of Defense for Policy, based on Administration guidance and inputs from the Joint Chiefs of Staff, the Unified and Specified Commands (CINCs),[10] the Service Secretaries, other OSD Staff (including the DDR&E), and other relevant sources. Once the Guidance is approved and published, the Services use it to build their respective programs, including their science and technology programs. There are

6Task Force Report, ''The Improved Coordination of DoD Science and Technology Programs" (Alexandria, VA: Institute for Defense Analyses, July 1988). At the request of the DDR&E, IDA assembled a [ask force consisting of numerous S&T managers from the Services and OSD to examine approaches for improving coordination of DOD's technology base programs.

7The Services have conducted impressive technological forecasting activities, including the Air Force's Forecast II study, the Navy's 21 study. and the Army's proposed Strategic Technologies for the Army (STAR) study. Such studies have been used to establish S&T priorities in the Services. However, as the IDA Task Force indicated, these activities arc primarily pursued independently within each Service.

8Institute for Defense Analyses, op. cit., footnote 6, p. 3.

9Summary Report and Recommendations of the IDA Task Force on]improved Coordination of the DOD Science and Technology Programs (Alexandria, VA: Institute for Defense Analyses, July 1988), p. 11-2.

10A unified command, Composed of significant forces from two or more Services, has a broad, continuing mission (usually geographically based). A specified command, composed primarily of forces from one Service, has a functional mission. The eight unified commands are Europe, Pacific, Atlantic, Southern, Central, Special Operations, Transportation, and Space. The specified commands arc the Strategic Air Command, Aerospace Defense Command, and Military Aidi ft Command. The names of the commands designate their primary geographic or functional area of" responsibility. Central Command, created in 1983, is concerned with the Persian Gulf' region.

also various inter-Service requirements documents that help to gear technology to future defense needs.

Nevertheless, the current 120-page document provides only one page of guidance for the DoD-wide technology base programs. More could help generate a stronger technology base program. Such broad guidance allows the Services and DARPA to justify technology base programs that they view as being in their individual best interests, but which may or may not meet the overall future science and technology needs of the Department of Defense as a whole.

In the absence of a centralized S&T investment strategy, it is extremely difficult for the DDR&E to assess the technology base programs of the Services and DARPA, other than for technical merit. The 1983 Grace report indicated that planning which permits the bottom-up approach to predominate—the current situation-often results in duplication of effort, and ineffective coordination of science and technology programs.[11] OSD's technology base investment review is primarily an information gathering function. When the Services present their annual technology base investment strategy to the DDDR&E(R&AT), no formal written feedback is provided, although there are usually verbal comments. Until this year, each of the Service's programs was reviewed separately, making cross-Service comparisons difficult. The Defense agencies (primarily DARPA) are not required to participate in this process, although they usually do to a limited extent.

Under current conditions, OSD cannot ensure that DoD's technology base programs are well balanced, properly coordinated, and capable of meeting the current and future science and technology needs of DoD. On the other hand, it is clear that OSD would be unable to conduct an effective technology base investment strategy without the close cooperation and goodwill of the Services and DARPA. Because the Services currently dominate the planning process, and act independently of one another, any effort to consolidate this function in OSD could cause dislocation and disruption of existing technology base program management.

Establishing Research Priorities and Direction

The dominant position of the Services in determining technology base initiatives arises from, and contributes to, the lack of an overall technology base investment strategy. The Services have filled a power vacuum and now protect their power. Instead of working with OSD to establish priorities based on overall defense needs, the Services allocate resources based on their own views of their individual needs. A 1981 Defense Science Board study recommended that a DoD R&D investment strategy linked to future combat needs be utilized in technology base planning ". . . so that technologies funded through the allocation processes would be more explicitly and consistently related to future operational needs. " *[2]

In the absence of broad strategic guidance, individual Service goals tend to supplant more general strategic ones. As the primary civilian component within DoD, the Office of the Secretary of Defense is supposed to act as a counterbalancing force to the Services, working objectively with the Services and DARPA to develop an overall technology base strategy in the best interest of DoD as a whole. In principle, once the strategy is articulated, the Services and DARPA develop science and technology goals to achieve that strategy.

The implications of inadequate OSD guidance can be significant with regard to the types of technological priorities the Services are willing to support. For example, according to Samuel P. Huntington,13 the Services are extremely reluctant to support "orphan" functions that are not central to a Service's own definition of its mission or fighting doctrine. This can present great difficulties for setting well-balanced science and technology priorities, since modern technology has provided capabilities that may not coincide with traditional ap-

11'~esjdent's Private Sector Survey on Cost Control, " report of the Task Force on Research and Development, Executive Office of the President, Dec. 8, 1983, p. 30.

12U.S. Department of Defense, Office of the DDR&E, "Report of the Defense Science Board, 1981 Summer Study Panel on the Technology Base" (Springfield, VA: National Technical Information Service, November 1981), p. i-2.

13 Samuel P. Huntington, ''Organization and Strategy," in *Reorganizing America's Defense* (Washington, DC: Pergamon Press, 1985), p. 236.

preaches to mission accomplishment or to the accepted division of mission responsibility.

The Services are often reluctant to support technology base initiatives that challenge their current mission or fighting doctrine, and because they dominate the technology base planning process, they are in a position to discourage such initiatives.

Coordination of Technology Base Programs

DoD lacks a strong and focused coordinating capability for its science and technology programs. Although DoD has over 200 tri-Service and inter-agency coordinating groups, in general they have not been effective at providing high level coordination across the DoD-wide technology base programs. (However, some, such as the Joint Service Electronics Program [JSEP], have produced impressive results.) Coordination efforts are further hampered because a significant portion of DoD's science and technology programs are not under the direct purview of the DDDR&E(R&AT).

In its task force report on improved coordination of DoD S&T programs, the Institute for Defense Analyses concluded that it is necessary to differentiate between "technical interchange" and "programmatic coordination, " The IDA study concluded that currently there is much technical interchange among the Services, but very little programmatic coordination is aimed at identifying scientific or technological gaps and overlaps. The IDA study states that, without proper coordination, it is difficult to ensure that the total DoD S&T program is properly addressing the overall science and technology needs of DoD.[14]

OSD uses annual science and technology reviews to help evaluate and improve the coordination of its technology base programs. These reviews are designed to examine a particular technology base program element (PE)[15] (e.g., avionics) and the projects in that element. However, such reviews are not always effective. Due to manpower constraints, OSD can only conduct a limited number of S&T reviews each year. Further, since there is no uniform OSD-wide format for conducting the reviews, the methodology and thoroughness vary greatly. With over 200 coordinating groups producing a hodgepodge of different reports, it is very difficult for OSD to determine whether the resources of its technology base program are being allocated wisely.

The IDA task force made three major recommendations for strengthening science and technology coordination. The first is to establish a DoD-wide S&T Coordinating Group responsible for establishing 17 Technology Coordinating Panels (TCPs) for the entire S&T program. Membership of the TCPs would consist of senior R&D managers from the Services, the agencies including DARPA, and SDIO.

The TCP panel members would be kept up to date on the status of a particular technology, the justification for specific programs in which a technology is used, and why the users' needs necessitate the pursuit of that technology. The purpose of the TCP panels would be to reduce unwarranted technology duplication, ensure that resources in a particular technology area are well balanced, identify potential technology gaps, and identify critical long-lead-time technologies in a series of annual reports.

The second major recommendation is that OSD, the Services, the agencies, and SDIO develop a DoD-wide format for the annual TCP reports. DoD currently has no formal S&T reporting process for its 200 coordinating groups. If these 17 TCP groups are to be effective, IDA believes, they should produce consistent reports that outline important technology activities across all of DoD's S&T activities,

The third, and final, recommendation is to absorb and disband those existing coordinating groups that are not needed to support the work of the TCPs. IDA points out that each of the 17 TCPs would have under it a number of (existing) technology coordinating subgroups. For example, the TCP for Ships and Submarines would have three subgroups: Hulls, Hydrodynamics, and Machining. Each of the subgroups would be required to contribute to the TCP's annual report. Those not needed for this process would be disbanded.

[14] Institute for Defense Analyses, op. cit., footnote 6, P. 3.

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

Although these recommendations might help to improve technology base coordination, getting them accepted and implemented within DoD may prove to be difficult. Each of the recommendations would have to be approved by the DDR&E as well as the USD(A) and then implemented by the Services and the defense agencies. This is a process which in the past has proven to be very difficult. For example, although DARPA was invited to participate in the IDA study, no DARPA representatives attended the meetings of the task force or participated in writing the final report.

Distrust and misunderstandings among OSD, the Services, and DARPA are a major impediment to improving S&T coordination. Efforts by OSD to improve cooperation or coordination can be interpreted as an attempt to tell the Services and DARPA how to manage their science and technology programs. Some OSD representatives believe that the Services will pursue an independent path when possible. Accordingly, improved coordination among OSD, the Services, DARPA, and SDIO will be difficult to achieve.

Acting as a Strong Advocate for DoD's Science and Technology Programs

OSD currently lacks a strong defender of its technology base programs. A strong advocate would have two primary responsibilities: 1) presenting a comprehensive review and defense of DoD-wide technology base programs to Congress; and 2) acting as a strong proponent for the S&T programs within the DoD.

The IDA task force concluded that there is no single individual within OSD who is responsible for presenting and defending technology base programs before Congress or within DoD. The task force indicated that the USD(A) should provide high-visibility advocacy for the S&T programs and develop a coherent DoD-wide position statement on the technology base programs.[16]

The lack of an effective S&T advocate within OSD has contributed to the erroneous perception, in Congress and even within DoD, that the technology base programs have shared in the rapid growth of the RDT&E account. Between fiscal years 1984 and 1989, funding for DoD's RDT&E programs increased 20 percent in constant dollars (see table 2). During the same period, however, research (6.1) and exploratory development (6.2) funding declined 3 percent and 6 percent, respectively, in constant dollars. Between fiscal years 1984 and 1989, almost all of the growth in DoD's S&T programs can be attributed to SDI. When the SDI figures are included in DoD's S&T activities, they present a distorted impression of budgetary growth in the S&T programs. The DDR&E testified before Congress that the rapid growth of the SDI budget has strengthened the technology base programs of DoD. By contrast, IDA task force members expressed the belief that most SDI efforts have been of little use to the rest of DoD's S&T programs.

In recent years, OSD has been unable to present a comprehensive review of its technology base programs to Congress in a compelling way. For example, in DoD's fiscal year 1987 RDT&E report to Congress (the last year DoD produced such a report), all the major RDT&E goals were focused on short-term objectives. The report did not make adequate distinctions between technology base activities on one hand and development, testing, and evaluation activities on the other. OSD failed to connect technology base advancements with the development of current and future weapon systems. Finally, the report provided no information on how funding trends for technology base programs compared with the overall growth in RDT&E funding.

In some cases, OSD officials have not been able to prevent the Services from shifting funds away from their own S&T programs in order to support more immediate concerns such as procurement, or to prevent OSD from cutting technology base programs. This is clear in budget reviews, and was demonstrated recently when the Army cut funding for its research program by almost one-third and cancelled its In-House Laboratory Independent Research (ILIR) program.

As illustrated by table 3, the Army-like the other Services-supported consistent increases in its research program beginning in fiscal year 1980. However, in fiscal year 1987, when DoD faced budget constraints, the Army cut its research pro-

[16]Institute for Defense Analyses, op. cit., footnote 6, p. 9.

Table 2—DoD Technology Base Funding, Fiscal Years 1984 Through 1989 (millions of 1982$)

	1984	1985	1986	1987	1988	1989	% Change (constant $) 1984-1989
Basic Research (6.1)[a]	778	760	831	756	740	755	-3
Exploratory Development (6.2)	2,051	2,032	1,984	1,985	1,924	1,928	-6
Advanced Technology Development Without SDI	1,261	1,175	1,223	1,433	1,438	1,408[b]	12
SDI office	1,109[c]	1,243	2,318	3,156	2,957	2,849	157[d]
Total Technology Base With SDI	5,199	5,210	6,356	7,330	7,059	7,191	38
Total Technology Base Without SDI	4,090	3,967	4,038	4,174	4,102	4,342	6
Total RDT&E	24,829	27,371	29,322	30,464	30,568	29,663	19

ªThis category does not include funding for the University Research Initiatives (URI) Program.
ᵇThis figure does not include the transfer of $250 million of OSD-managed projects to DARPA.
ᶜAccording to DoD, although SDIO was allocated $49 million to begin its research activities, the three Services plus DARPA were already conducting about $1.2 billion in SDI-related research-in fiscal year I&34 (in 1984$).
ᵈReflects $1,250 million of SDI-related work in fiscal year 1984.

SOURCE: office of the Secretary of Defense.

Table 3-individual Service Funding for Research (6.1) (in millions of dollars)

Year	Army	Navy	Air Force
1980	130.7	214.9	119.2
1981	144.4	241.4	126.6
1982	179.2	276.5	147.4
1983	206.2	307.6	166.4
1984	216.5	320.6	191.4
1985	231.5	341.2	201.3
1986	250.3	342.3	210.2
1987	219.5	354.3	223.3
1988	168.9	342.1	197.7
1989	172.7	355.3	196.4

SOURCE: office of the Secretary of Defense.

gram by 12 percent and cancelled its ILIR program for fiscal year 1988. In fiscal year 1987, ILIR comprised about 7 percent of the Army's research budget, or $16 million, spread among its 31 laboratories on a competitive basis.

The ILIR programs serve a number of important purposes for Service laboratories. Because they are a principal main source of discretionary research funds, the Service ILIR programs help the labs maintain an atmosphere of creativity and research excellence, enhance their S&T base, provide seed money that can lead to new research efforts, and assist the laboratory directors in hiring new Ph.D.s.

In its 1987 summer study on technology base management the DSB stated that ''a successful laboratory requires discretionary basic research funding for its long term vitality. '' The DSB went on to recommend that "at least 5 percent, and up to 10 percent, of the annual funding of Federal laboratories" should consist of ILIR funds.[17]

In meetings with OSD the Army reassured the DDDR&E(R&AT) that funding for the research program would be restored as soon as possible. However, in fiscal year 1988, the Army cuts its research program an additional 23 percent, and canceled the ILIR program. After several meetings with top Army RDT&E officials, the DDDR&E decided not to raise the 6.1 funding issue to the DDR&E level.

Promoting Cooperation Among the Services and DARPA

There is a long history of inter-Service rivalry and difficulty in cooperation between the Services and OSD. Further, cooperation between the Services and DARPA is hindered because DARPA reports to the DDR&E while the Service S&T representatives report to the DDDR&E(R&AT). Starting with the National Security Act of 1947, Congress has taken a number of steps to strengthen OSD as a centralizing and coordinating body. Many analysts believe that these efforts have generally

[17]U.S. Department of Defense, Office of the DDR&E, Report of the Defense Science Board, 1987 Summer Study on Technology Base Management" (Springfield, VA: National Technical Information Service, December 1987), p. 15.

been unsuccessful.[18] It is probably too early to tell if the recent Goldwater-Nichols Act will be successful in improving OSD centralization and coordination capacity.

Inter-Service rivalry is not necessarily all bad. In his book *Bureaucracy and Representative Government,* William Niskanen states that ‘‘competition among bureaus promotes efficiency by reducing the cost of certain services. ” Niskanen points out that redundancy can guard against catastrophic failure of one or more programs. [19]

Certainly there are advantages in using competitive approaches. However, there are limits to the extent to which competition can contribute to the success of the DoD S&T program. In an environment where the rapid development and deployment of a technology often is important, excessive competition usually results in poor coordination, which slows the introduction of new S&T capabilities. Representatives from OSD and the Services have stated to OTA staff that inter-Service rivalry often has played a major role in delaying the development of important technologies (such as remotely piloted vehicles).

There have been instances in which OSD, the Services, and DARPA have been able to overcome some of these difficulties. One example is the recent establishment of the Balanced Technology Initiative (BTI). Established by Congress in fiscal year 1987, the BTI is intended to develop new technologies to ‘‘substantially advance our conventional defense capabilities. ” The National Defense Authorization Act for fiscal year 1987 indicated that BTI funds were to be used to ‘‘expand research on innovative concepts and methods of enhancing conventional defense capabilities,” and to promote “restoration of the conventional defense technology base. ”[20] Responsibility for planning, development, and oversight of the BTI program was assigned to the DDR&E. The makeup of the BTI planning team, chaired by a representative from the office of the DDDR&E(R&AT), was unusual because it included the Services, DARPA, SDIO, and four other OSD organizations: Tactical Warfare Programs, Strategic and Theater Nuclear Forces, International Programs and Technology, and the Undersecretary of Defense for Policy. Funding for the program was appropriated by Congress to OSD to be divided among the Services, SDIO and DARPA.

Despite initial skepticism by the Services and DARPA, the BTI program appears to enjoy strong, although not universal, DoD and congressional support. One reason might be that OSD did not develop program guidelines on its own and then ask the Services and DARPA to forward proposals based on those guidelines. Rather, OSD made a deliberate decision to include all of the interested parties in the process of developing the BTI guidelines. All of the participants played a role in the development of its overall goals, and knew that project selection was tied to the ultimate goals of the program rather than just technological competence.[21] OSD officials tried to take advantage of European technological knowledge and capabilities during the initial planning stages. The BTI planning team was also successful in designing broad project implementation and evaluation procedures. Finally, the BTI report to Congress tied each of the programs to a crucial component of the air-land and maritime strategy, not to a program funding element; essentially, the BTI planning team tied each project to a component of the conventional warfare doctrine.

It is still too early to evaluate the success of the BTI. Like other congressionally mandated programs, the BTI was greeted with skepticism in the Services and OSD because congressional interest and funding support for such special initiatives often

[18] Daniel J. Kaufman, “National Security: Organizing the Armed Forces, ” *Armed Forces & Society,* Mar. 16, 1988, p. 15.

[19] William Niskanen, Bureaucracy *and Representative Government* (Chicago, IL: Aldine, Atherton, 1971).

[20] Robert C. Duncan, DDR&E, *Department of Defense Statement on the Balanced Technology Initiative,* presented before the Committee on ‘reed Services, U. S. Senate, Apr. 11, 1988, p. 2.

[21] Guidelines for selection included the following: 1) Projects had to be consistent with the stated intent of Congress. 2) Emphasis had to be on technology areas that address recognized conventional force needs (e.g., chemical, biological defense, and nuclear programs were generally excluded). 3) Projects should offer both short- and long-term potential for enhancing conventional force needs. Preference would be given to ongoing work that offered a high payoff in military effectiveness, with limited additional funding. 4) SDIO suggestions should be presented as technological spinoff opportunities with relevance to conventional defense needs (e.g., hypervelocity guns and projectiles, high-power microwaves, and advanced seekers and sensors). 5) A certain number of projects had to involve joint programs, such as Services/DARPA, multi-Service, or international cooperation.

have been fleeting.[22] Nevertheless, rather than developing program guidelines and objectives independently, OSD appears to have tempered this skepticism by creating an environment in which all interested parties are willing to cooperate in the development and implementation of the BTI program.

Evaluating the Goals of the Technology Base Programs

OSD and the Services have not developed a systematic, DoD-wide approach for determining the extent to which technology base programs actually satisfy goals set by OSD. OSD officials and Service representatives typically describe two goals of the S&T programs: maintaining technological superiority over the Soviet Union, and being a smart buyer of technology and technological expertise. Other technology base goals, such as reducing complexity and cost, improving productivity of the industrial base, sponsoring the highest-quality S&T work, and enhancing return on investment, receive comparatively little emphasis.

Moreover, although there is seemingly a general consensus on what it means to keep ahead of the Soviet Union, there appears to be much less agreement regarding what it means to be a‘ ‘smart buyer. ” OSD and the Services appear to have no systematic way of determining whether they are smarter buyers of technology and weapon systems today than they were, say, 10 years ago. It appears that OSD and the Services take it “on faith” that a sustained effort in various S&T activities provides them with the ability to make intelligent investments in S&T and weapon systems development.

Evaluating Research Activities

When OTA asked OSD representatives how they spent their time, the responses focused on three things. First, most of the respondents said they spend too much time on the long process of reviewing and defending their programmatic budgets. Second, OSD personnel spend time responding to DoD internal requests. These requests include technical questions, providing information for the DoD Inspector General, responding to General Accounting Office audits, or trying to prevent one of the Services from shifting funds away from an S&T program. Third, the respondents indicated that they spend more and more of their time trying to satisfy congressional requests. According to a recent article, in 1970 Congress requested 31 reports or studies from OSD. By 1985 that number had climbed to 458. Concomitantly, legal provisions detailing how DoD is to carry out certain aspects of its responsibilities have increased from 64 to 213, while annual congressionally mandated actions requiring specific DoD compliance increased from 18 to 202.[23] OSD representatives gave the impression that they were drowning in a sea of internal and external accountability and bureaucratic red tape.

Many respondents indicated that they spent only a small portion of their time performing duties that require science and technology skills. It appears that too many OSD-as well as Service-R&D managers are required to spend an inordinate amount of time defending their budgets, responding to DoD bureaucratic red tape, or answering an ever-growing number of congressional inquiries, leaving little time to evaluate R&D activities.

ORGANIZATION OF OSD FOR OVERSIGHT

DoD’s current organizational arrangement for managing S&T activities contributes to the difficulties OSD encounters in shaping a coherent technology base strategy, and to the problems described above.

As a result of 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 USD(A). The legislation also re-created the Office of the DDR&E, which reports to the USD(A). (See figure 2.)

The USD(A) has oversight responsibility for all of DoD’s technology base programs, except those of SDIO, That oversight responsibility is delegated to

[22] The Services are generally satisfied with the conventional programs the BTI is currently supporting. However, Congress did not Provide any additional funding for the BTI in fiscal year 1990. Consequently, OSD will fund the BTI program by taxing other conventional technology base efforts of the Services. The Services argue that OSD’s action in this instance has greatly compromised the original intent of the BTI program,

[23] Kaufman, op. cit., footnote 18, P. 5.

the DDR&E, who in turn delegates oversight of the Services' programs to the DDDRE(R&AT). The director of DARPA is supposed to work closely with the DDDR&E(R&AT), but reports directly to the DDR&E.

The current DoD RDT&E organizational structure raises a number of concerns. The first centers on the primary responsibilities of the USD(A). The Packard Commission stated that it was crucial for the new USD(A) to have full-time responsibility for managing the defense acquisition system, setting R&D policy, and supervising the performance of the entire process including procurement, logistics, and testing. The Under Secretary is also responsible for developing contract audit policy, supervising the oversight of defense contractors, and preparing annual reports to Congress on major issues of acquisition policy and program implementation. With the procurement budget many times larger than the tech base budget, members of the defense R&D community are afraid that their concerns will take a back seat to the USD(A)'s broad menu of acquisition responsibilities.

Some OSD and Service representatives believe that it is too early to tell whether the technology base programs will suffer as a result of the reorganization. However, other DoD officials contend that S&T programs have already experienced some setbacks. They note, for example, that the USD(A) recently removed the office responsible for international R&D cooperative programs from the DDR&E's office. The newly created Deputy Under Secretary of Defense for International Programs and Technology is still responsible for cooperative foreign R&D programs but now reports directly to the USD(A). However, according to the 1986 Nunn Amendment, by 1994, 10 percent of the RDT&E programs are to have foreign involvement. Representatives of the office of the DDR&E believe that they should have oversight responsibilities for those programs. Currently there are about 20 foreign S&T cooperative projects.

A second organizational problem concerns the reestablishment of the DDR&E. The DDR&E was originally established as part of the 1958 Department of Defense reorganization Act. The DDR&E was given greater responsibilities in 1977, and elevated to the Under Secretary of Defense for Research and Engineering [USD(R&E)] as part of Secretary of Defense Harold Brown's management reforms.

Some DoD officials contend that the reestablishment of the DDR&E as subordinate to the USD(A) might be interpreted as a lowering of status for R&D, since the DDR&E no longer has direct access to the Secretary of Defense. Various OSD representatives have argued that if science and technology are the cornerstone of the military's defense capabilities, then S&T programs should have direct access to the Secretary's office. They fear that, without such direct access, important S&T issues such as cooperative foreign R&D programs will get lost in the acquisition shuffle. Others, however, assert that only technology that gets fielded in military systems has any value for defense, and that the DDR&E is appropriately placed under the USD(A). They claim that the reestablishment of the DDR&E will not present a problem if the USD(A) strongly supports the S&T programs.

Managing Technology Base Activities at DARPA and SDIO

The Role of DARPA

A third concern is the role that DARPA and SDIO play in supporting DoD's technology base programs. DARPA was established in 1958, partly as a result of the launching of the initial Sputnik satellites. The President and Congress also recognized that DoD needed an organization that 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, 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 potential payoff are both high, and where success might 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 that hold promise for important technology advancement for all of the Services,

DARPA executes its programs mainly through contracts with industry, universities, nonprofit organizations, and Government laboratories. DARPA now has a limited in-house contracting capability, but most of its contracts are still managed by the Services.

Although DARPA was originally established as a small agency to promote the rapid diffusion of new and creative ideas, in the past two years DARPA's budget has ballooned to over $1 billion, sponsoring almost 25 percent of the military's S&T work.[24] Further, in 1986 DoD announced that DARPA's role as a developer of technology would include prototyping.

The recent rapid growth in DARPA's budget and its additional prototyping responsibilities have raised several concerns within the defense community. First, OSD and Service representatives have had problems coordinating technology base activities with DARPA. They contend that part of the problem is DARPA's independence and its separate reporting chain within OSD. All three Services have complained that DARPA seldom involves them in its initial planning activities for joint DARPA/Service projects. The Services note that DARPA often chooses not to participate in important technology base activities. Many experts believe that efforts to improve DoD-wide technology base planning and coordination would require full participation by DARPA.

A second concern revolves around the changing nature of DARPA's technology base activities. Of the $1,270 million DARPA budget for fiscal year 1989, only $88 million is for basic research. There is growing concern, inside and outside DoD, that DARPA may be supporting too much applied research and technology demonstration activities rather than longer-term, high-risk basic research. In testimony before the House Science and Technology Committee's Task Force on Science Policy, Norman R. Augustine, a member of the DSB and then the executive vice president of Martin Marietta corporation, stated that:

> In decades past, the effort of the [Defense] Advanced Research Projects Agency was focused upon advancing basic research and applied research. Over the years since its inception, however, the funds allowed to DARPA have been, to an increasing degree, used for prototype demonstrations-a very worthwhile undertaking in its own right but nevertheless still a major drain on the basic research resources originally intended at the time DARPA was established.[25]

The changing nature of DARPA's technology base work leads to a third organizational issue: DARPA's alleged past difficulties in transferring technology to the Services. DARPA is not the only organization, public or private, to struggle with technology transfer problems, and over its 30-year history DARPA has had a very impressive record of successfully transferring such technologies as stealth, directed energy, and some types of lasers to the Services. Nevertheless, many OSD and Service representatives strongly criticized DARPA's current technology transfer activities, particularly with regard to prototyping and technology demonstration programs. This has taken on particular importance in recent years, as Congress has turned to DARPA to address Service-related advanced technological problems in such areas as anti-submarine warfare, anti-armor applications, and lighter-than-air technology.

Two recent studies seem to reinforce the OSD and Service technology transfer concerns. In 1985, at DARPA's request, both the National Security Industrial Association (NSIA) and the Technology Transfer Center at George Mason University conducted studies of the particular technology transfer process associated with DARPA's large technology demonstration programs. Both of these studies concluded that DARPA's technology transfer activities rely too much on individual initiatives, resulting in a very weak and haphazard approach to the technology transfer process. The NSIA study noted that "DARPA is often too insensitive or unaware regarding the needs and problems of the Services. " The NSIA

[24] OSD estimates that for fiscal year 1989 DARPA's budget will be about $1,270 million. Of that amount, $250 million will consist of work transferred out of OSD to DARPA. These projects include the SEMATECH initiative, the Monolithic Microwave Integrated Circuit (MMIC) program, the Software Technology for Adaptable Reliable Systems (STARS), and several other programs. The OSD projects will be primarily managed by OSD personnel who have been transferred to DARPA from the disbanded Computer and Electronics Technology Directorate in OSD. The remaining $1,000 million (approximately) consists of about $700 million requested by DARPA and a total of about $300 million added on by Congress,

[25] Norman R. Augustine, Martin Marietta Corp., testimony at hearings before the House Committee on Science and Technology, Task Force on Science Policy, Oct. 23, 1985, pp. 3-4.

panel indicated that an "increase in the awareness and sensitivity to the Services needs need not compromise DARPA's essential free thinking. "[26]

Both studies recommended that DARPA develop a written Agency-wide technology transfer plan for all technology demonstration activities. Among other things, this plan should *require all* program managers to work closely with the appropriate Service when undertaking a technology demonstration project. Both studies recommended that DARPA make available to all Program Managers a central historical database of successful and unsuccessful technology transfer strategies based on actual program experience. The studies pointed out that given the short tenure of DARPA professional staff (about 3 to 4 years), a written plan and central database would help improve the long-term continuity of DARPA's technology demonstration programs.

Despite these strong recommendations, DARPA has not yet developed a formal technology transfer plan. OSD and the Service representatives assert that if DARPA continues to pursue its technology transfer activities as it has in the past, many good technological opportunities could be wasted. However, this problem is not unique to DARPA; OTA has not found any formalized written technology transfer procedures developed by OSD and the Services.

The Role of SDIO

The Strategic Defense Initiative Organization (SDIO) was established as a separate agency of the Department of Defense in 1984, with the director reporting to the Secretary of Defense. The SDIO's mission is to ''provide the technological basis for art informed decision regarding feasibility of eliminating the threat posed by ballistic missiles and increasing the contribution of defensive systems to U.S. and allied security. "[27]

As indicated in table 3, the SDIO budget has grown rapidly over the past 5 years. Although the entire SDIO budget is contained within the 6.3A budget category, not all SDI activities are advanced technology demonstration efforts. For example, SDIO's Innovative Science and Technology Office (ISTO) has the mission of establishing the feasibility of revolutionary concepts with the potential for application to specific SDI technological needs. Like DARPA, the ISTO executes its research contracts through the Services. The ISTO estimates that in fiscal year 1988 and fiscal year 1989 it will support $100 million in SDI-related research.

SDIO also supports exploratory development (otherwise funded under category 6.2). Because there is no separate office that manages such work, it is very difficult to determine how much exploratory development SDIO is currently funding. OTA asked SDIO if it could determine the dollar amount of research and exploratory development projects it supports on an annual basis. According to the SDIO comptroller, SDIO does not fund any true research activities.[28] SDIO's research efforts do not match DoD's accepted definition of research. However, the director of ISTO indicated that 80 percent of the projects his office supports do qualify as research. OSD and Service representatives agree that ISTO sponsors short-term research programs, with heavy emphasis on solving specific SDIO challenges.

The comptroller maintains that all of ISTO's efforts really fall under the definition of exploratory development. The report concludes that approximately 20 percent of the SDIO budget is devoted to exploratory development work.

SDIO is funding about $700 million of exploratory development work with no formal coordinating ties to the three Services and DARPA. Presently, the only coordinating activities occur informally, as the individual Services and DARPA manage SDIO's exploratory development contracts. OSD and Service representatives have stated that SDIO should participate in OSD's technology base investment strategy activities. Taken together, the current organizational arrangement and the mission of the SDIO program make such participation unlikely. According to the Air Force, however, SDIO projects conducted in Air Force laboratories

[26] National Security Industrial Association, "DARPA's Technology Transfer Policy," December 1985, p. 7.

[27] Gerald Yonas, Acting Deputy Director and Chief Scientist of SDIO, "The Strategic Defense initiative Science in the Mission Agencies & Federal Laboratories," testimony at hearings before the House Committee on Science and Technology, Science Policy Task Force, Oct. 23, 1985, p. 543.

[28] The comptroller of SDIO provided OTA with a written estimate of how milch technology base work SDIO is currently supporting, by category.

differ from DARPA projects because they are well integrated into the laboratory program. Such coordination and integration usually occurs at the laboratory (or lab division) level.

Recruiting and Retaining Scientific Personnel

According to OSD and Service representatives, DoD is often unable to recruit the very best scientific, technical, and managerial talent. Because of growing salary disparities between the government and the private sector, OSD is losing many top level S&T managers.

The late Philip Handler, former president of the National Academy of Sciences, once pointed out that in science the best is vastly more important than the next best. Both the 1983 Packard Report and the 1987 DSB report concluded that OSD and the Services face serious disadvantages in hiring and retaining top S&T personnel for three primary reasons: inadequate civil service compensation, ‘‘revolving door” restrictions, and a lowering of status associated with Federal employment.

A recent unpublished Navy study found that since the early 1980s, the disparity between Federal salaries and salaries in industry and academia has greatly expanded. For example, the average compensation for S&T managers in the upper 10 percent of the private sector was $40,000 to $50,000 higher than for their Government counterparts. Another internal Navy survey of university principle investigators (PIs) found that, for the first time, the majority of PIs’ salaries were higher than government salaries. Some 60 percent of university PIs are paid salaries that exceed the Federal pay cap, with approximately one-third of them exceeding $90,000.

This problem is likely to become more pressing in the future. Changing demographics will produce a work force with greater ethnic diversity and more women. Minorities and women have not contributed in substantial numbers to science and engineering in the past. The challenge will be to expand the participation of women and minorities in science and engineering college programs and graduate schools and, ultimately, to offer them rewarding careers working in defense technology base and related program areas.[29]

Salary disparity has also contributed to a high level of turnover among top-level OSD political appointees. For example, between 1981 and 1988 there were three different USD(R&E) officials, and five individuals have held the position that is now DDDR&E(R&AT). An internal OSD study indicated that the overall quality of its S&T political appointees was very inconsistent.

Pre-employment and post-employment personnel restrictions also mitigate against recruiting first-rate political appointees. Such officials are required to divest themselves of any financial interest in any company conducting business with DoD. This requirement can result in serious tax consequences for the political appointee. Further, many prospective employees resent the prospect of filing an annual financial disclosure statement.

The main postemployment restriction concerns the recently amended “revolving door” legislation. The revised law restricts the kinds of services former military officers and DoD employees may perform for a future employer that does business with the Defense Department. Among other things, this law imposes a‘‘2-yearban on certain former Department of Defense personnel receiving compensation of more than $250 from defense contractors (who have contracts in excess of $10 million with the government) if the former officers or employees had official procurement duties relating to that contractor during the 2-year period prior to separation from government service. ”[30]

According to OSD and Service representatives, the revolving door legislation has significantly limited DoD’s ability to hire top-level S&T managers from the private sector who have had experience working in the defense arena. Compared with their predecessors, many top-level S&T managers now

[29] U.S. Congress, Office of Technology Assessment, *Educating Scientists and Engineers: Grade School to Grad School* (Washington, DC: U.S. Government Printing Office, June 1988); and U.S. Congress, Officeof’Technology Assessment, *Higher Education for Scientists and Engineers—Background Paper, OTA-BP-SET-52* (Washington, DC: U.S. Government Printing Office, March 1989).

[30] Jack Maskell, Library of Congress, Congressional Research Service, ‘‘Post Employ ment ‘Revolving Door’ Restrictions on Department of Defense Personnel,” July 5, 1988, p. 3.

come to DoD with little or no defense experience. This situation has contributed to the increasing period of time it takes new DoD S&T managers to understand the complexities of the overall defense environment.

DoD SUPPORT OF ITS TECHNOLOGY BASE PROGRAMS

In 1953, President Eisenhower said that, despite the establishment of the National Science Foundation, Federal agencies such as DoD would have to continue performing and supporting basic research closely related to their missions. Since then DoD officials have asserted that basic research provides information on natural phenomena that DoD could use in the development of modem weapons.

In 1963 Harold Brown, then DDR&E and subsequently Secretary of Defense, said that ‘‘as the largest user of scientific and technical information in the Federal Government, DoD had an obligation to replenish this information. ” Brown went on to say that DoD has to support a broad range of research that may or may not be directly related to its mission.[31] DoD representatives contend that in an era of rapid technological change and growing Soviet S&T competence, DoD support for a strong and diverse technology base program is imperative.

Despite these strong statements of support, funding for DoD’s S&T programs has been inconsistent over the past 20 years. As table 4 indicates, beginning in 1970, funding for research (in constant dollars) began to decline and did not exceed its 1970 level of support until 1986. Moreover, since the peak year of 1986, funding for research has declined more than 4 percent in constant dollars.

Similarly, support for exploratory development declined until the late 1970s. Then it rebounded, nearly returning to its 1970 level by 1983—in constant dollars, Between 1984 and 1989, however, support for exploratory development again fell by almost 10 percent.

By almost any measure—total constant dollars, fraction of DoD budget, fraction of RDT&E budget—the level of DoD support for its research and exploratory development programs has decreased over the past 20 years. In the mid-1960s, research and exploratory development represented 25 percent of the total RDT&E budget. By 1989 it had shrunk to less than 9 percent. Between 1970 and 1988, 6.1 and 6.2 funding declined as a percent of DoD’s total obligational authority (TOA), from 1.79 percent to 1.27 percent. Further, as table 4 shows, since 1983 DoD has moved its resources from research and exploratory development programs to advanced technology development (ATD) programs.

Between 1984 and 1989, constant dollar funding for 6.1 and 6.2 programs declined 3 percent and 6 percent, respectively (see table 2). During the same period, funding for advanced technology development (ATD) exclusive of SDI increased 12 percent, while support for the SDI program rose 157 percent,[32]

The recent rapid growth of both ATD and SDI programs has taken its toll on the basic research and exploratory development programs. OSD and Service representatives have indicated that DoD is putting greater emphasis on ATD activities to improve the transfer of new technology to weapon systems. For example, in 1984 DoD reduced funding for its exploratory development program by $300 million while increasing ATD by $500 million. According to OSD personnel, the switch in funding was nothing more than an accounting change: a review of the programs supported under exploratory development revealed that a good portion of the work should have been classified as ATD.

In testimony before the House Armed Services Committee, the DDR&E, Dr. Robert Duncan, said that the growth in the ATD program and the SDI program has offset the losses in research and exploratory development. However various OSD and Service representatives contest this statement, insisting that those technology base activities which SDI currently supports are aimed exclusively at solving SDI-related problems. Consequently, potential benefits flowing from SDI into technology base programs will be long term, and probably more

[31] Ralph Sanders (cd.), ‘‘Research: Meaning of the Term,” in *Defense Research and Development* (Washington, DC: Industrial College of the Armed Forces, 1968), p. 73. ‘

[32] This calculation is based on DoD information that the three Services and DARPA were supporting about $1.2 billion in SDI-related research in 1984.

Table 4—DoD Technology Base Funding Trends (millions of 1982$)

Year	Research (6.1)	Exploratory Development (6.2)	Advanced Technology Development (6.3A)	SDIO[b]	Total without SDI	Total with SDI
1970	779	2,418	—	—	3,197	—
1971	728	2,238	—	—	2,966	—
1972	712	2,414	—		3,126	—
1973	629	2,306	—		2,935	—
1974	579	2,126	567		3,273	—
1975	530	1,923	631	—	3,084	—
1976	528	1,902	677		3,107	—
1977	556	1,947	734		3,237	—
1978	576	1,937	697		3,210	—
1979	608	1,972	725		3,306	—
1980	653	2,021	676		3,350	—
1981	660	2,134	600		3,393	—
1982	697	2,233	738		3,668	—
1983	754	2,357	792	—	3,903	—
1984	778	2,051	1,261	1,109	4,090	5,199
1985	760	2,032	1,175	1,243	3,967	5,210
1986	831	1,984	1,223	2,318	4,038	6,356
1987	756	1,985	1,433	3,156	4,174	7,330
1988	740	1,924	1,438	2,957	4,102	7,059
1989	755	1,928	1,658	2,849	4,342	7,191

[a]The 6.3A category was established in 1974.
[b]Established in 1984.

SOURCE: Office of the Secretary of Defense.

expensive than if they had been supported directly through S&T activities.

The IDA task force stated the consequences bluntly:

> If the decline in resources devoted to science and technology is not reversed, the impact on the related technological capabilities of U.S. weaponry and forces maybe compromised so much that we will need to rethink our basic strategy of using qualitatively superior weapons to offset numerical disadvantages.[33]

While DoD's RDT&E program has experienced significant growth in the 1980s (see figure 3) the S&T portion of the budget has not shared in that expansion. Between 1980 and 1989 the RDT&E budget increased 90 percent in constant dollars, while the S&T programs (excluding SDI) increased only 16 percent.

According to OSD and Service representatives, two primary reasons explain this relatively small increase. First, technology base programs do not enjoy strong support at the highest levels within the military. Similar findings were reported by the IDA task force, and the DSB in its 1987 summer study of DoD S&T programs. In its report the DSB stated:

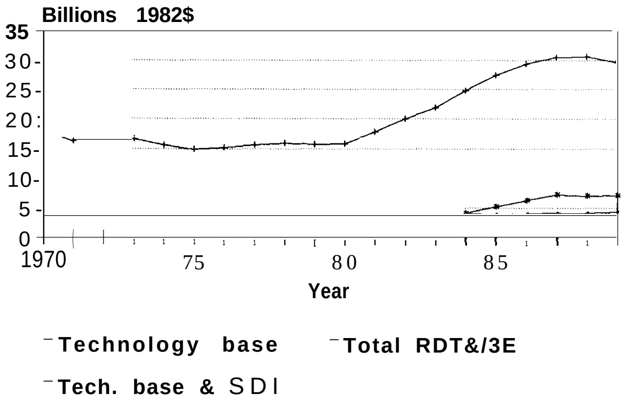
> Where once OSD exerted a centralized point of unified leadership and budgetary authority and control for the 6.1 program, the Study Group is concerned that this leadership is fragmented by delegation to the Services and agencies; the 6.1 program has, in effect, been relegated to a position of second or third order of importance and lacks top management attention. Stated bluntly, DoD "corporate management" has essentially abrogated some of its responsibility for long range vitality and competitiveness.[34]

OSD and Service representatives believe that military leaders do not appreciate the role that past S&T accomplishments have played in providing technologically superior weapons. Top Pentagon leaders are often willing to sacrifice 6.1 and 6.2

[33]Institute for Defense Analyses, op. cit., footnote 6, p. 4.

[34]U.S. Department of Defense, op. cit., footnote 17, p. 13.

Figure 3-Comparison of RDT&E and Technology Base



SOURCE: Data provided by the Office of the Secretary of Defense,

activities in order to protect budgets for immediate and visible needs, such as tanks and planes. The consequences of reducing the force structure, terminating weapon systems, or delaying procurement are much more visible than a particular research program which may not bear fruit for 10 to 15 years, if ever. Unfortunately, this attitude has not served the technology base programs well in times of tight budgets. It has resulted in military leaders 'raiding" S&T programs to help pay for downstream system development programs. As was noted earlier, the recent growth in the ATD budget to improve DoD's near-term technology transfer concerns has come at the expense of the research and exploratory development,

Focusing on near-term defense needs in resolving budgetary conflicts tends to bias the subject matter of DoD research. There is considerable agreement within OSD and the Services that much of DoD's research program is aimed at meeting the short-term needs of the military, and that it is easier to obtain top-level support for research activities that can be related to specific military needs. This is a point of contention. Many of those actively involved in the S&T programs believe that this is a misuse of research funds. They contend that it is unwise to direct the research program toward the solution of near term problems because military utility can come from all areas of science and engineering. By this logic, it is in DoD's best interest to be involved in a wide range of research problems, to follow their progress carefully, and to apply long term scientific reserch to present and future needs.[35]

A recent internal OSD evaluation of DoD's research programs concluded that many of its research projects in such fields as mathematics, chemistry, computer sciences, and physics were ''too well connected to current military needs. " The OSD review instructed Service 6.1 managers that "you should be reaping the fruits of seeds sown by your predecessors, and you should be sowing the seeds which will bear fruit for your successors several times removed. "

This very same concern was discussed in the DSB's 1987 summer study on the technology base. The DSB report concluded, "The need for short-term results and immediate 'relevancy' has become the governing criterion in framing a program. We have experienced a 'research menu squeeze' in which the most popular programs, justifiable in terms of clearly perceived near-term military relevancy, survive the cut."[36] The DSB report urged the Services to pursue more research activities with longer term objectives. On the other hand, some argue that basic research is funded within DoD precisely because the Defense Department can give it a focus that makes it relevant to military needs.

CONCLUSION

There is a serious question as to whether OSD is currently fulfilling its technology base oversight responsibilities in a satisfactory way. There is general agreement, inside and outside of the Pentagon, that OSD has not developed an overall technology base investment strategy. Many within the Services contend that, for a number of reasons, OSD should not attempt to develop a coordinated technology base investment strategy, and that the current decentralized system is probably better. But others assert that such a large technology base program, with important national security implications, ought

[35] George Gamota, ''How Much Does the Defense Department Advance Science?" in proceedings of an American Association for the Advancement of Science (AAAS) symposium, Naval Research Center, Washington, DC, Jan. 8, 1980 (published Sept. 24, 1980), p. 4.

[36] U.S. Department of Defense, op. cit., footnote 17, p. 12.

to possess some overall central leadership and guidance.

Implementing an OSD-guided investment strategy would not be a panacea for all the challenges confronting DoD's technology base programs. A coordinated investment strategy could: 1) help create a process for making OSD-directed strategic decisions, 2) allow OSD and the different agencies to focus on the outputs of the S&T programs and not just the inputs, and 3) enhance the understanding of DoD technology base programs.

A coherent technology base investment strategy would assist Congress in its review of defense S&T programs. In the absence of a clearly articulated technology base strategy, Congress is forced to focus its review on numerous individual program elements. A technology base strategy that included a rational list of priorities would enable Congress to take a broader view of the Pentagon's S&T programs. Congress might then focus its attention on the extent to which DoD's proposed technology base program satisfies its overall strategy and stated priorities.

Despite the Goldwater-Nichols Act, OSD's current organizational arrangement presents problems for coordinating the different technology base programs. Without the full participation of DARPA and SDIO, a coherent technology base program will be very difficult to achieve.

Clearly there is no magic formula for DoD to use in determining the ''right" level of support for its technology base programs. After numerous discussions with individuals outside and inside the defense community, OTA has identified several criteria that might usefully be applied to evaluating the overall strength of DoD's science and technology programs.

First, it is essential for an organization to maintain strong support for a broadly based science and technology program, Top corporate managers, responsible for maintaining the overall health of their science and technology programs, must have a deep understanding of how a strong technology base program can help an organization attain both its short and long term S&T goals. DoD's technology base programs do not enjoy consistent high-level support within OSD and the Services. An organization's research program should be strong and diverse enough to attack any problem related to the organization's mission. As the director of research for a large industrial corporation told OTA, he wants his S&T people to be "swimming in a sea" of company-t-elated research problems.

Second, individuals responsible for managing S&T programs need a clear mission statement that guides the overall makeup of the S&T programs. The mission should be developed by a critical number of people throughout the organization and understood by all. DoD asserts that the primary mission of its S&T programs is to offset the numerical advantages and growing technological sophistication of Soviet forces. But recent studies criticize DoD for focusing too strongly on the Soviet Union, arguing that the military must be prepared to engage in a number of different combat arenas.[37] There is little agreement within OSD and the Services on how the technology base programs should be structured to meet the diverse security challenges that will confront DoD in the future.

Third, a strong S&T organization must be able to recruit, hire, and invest in the very best S&T talent. These new people should be exposed to a strong orientation program that helps them understand how their work will contribute to attaining the overall S&T mission. In order to conduct a vital S&T program, DoD must achieve the ability to recruit and retain top flight scientists and engineers,

Fourth, many researchers, both inside and outside the Pentagon, contend that DoD needs to maintain greater funding stability for its technology base programs. This is especially true for the early stages of research activities.[38] DoD's research and exploratory development programs have suffered since the establishment of SDI. Over the last six fiscal years (1984-89), DoD has been the only major Federal R&D sponsor to experience a funding decline, in constant dollars, for basic research. A continuation

[37] See, for example, Fred C. Ikle and Albert Wohlstetter, ''Discriminate Deterrence," Report of The Commission On Integrated brig-Term Strategy, Jan. 11, 1988.

[38] U.S. Department of Defense, op. cit., footnote 17, P. 11.

of these trends could jeopardize a pillar of U.S. defense strategy.

The director of research at a Department of Energy (DOE) laboratory speaks of "recovery research." When an organization fails to support a broadly based research program, it often experiences difficulty with new products as they move into development. Consequently, in order to correct such problems, the organization is forced to engage in recovery research, which is costly and time-consuming. The DOE official stated that the more an organization has to perform recovery research, the greater the probability that its S&T programs are not receiving enough support. An OSD official told OTA that he believes that DoD has to support too much recovery research.

Finally, a strong S&T program must be closely coupled to the developers and ultimate users of technology. This is an important avenue of communication for managers to ensure that their S&T programs are solving the right problems, Some Service officials complain that technology base people are not always consulted when new weapon specifications are developed. For example, Army S&T representatives told OTA that they were not consulted when the Light Helicopter Experimental program specified an automatic target recognition capability (ATR). According to these officials, they knew that an ATR capability was (and still is) not feasible. The Army now refers to this concept as aided automatic targeting recognition (AATR).