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THE DEPARTMENT OF DEFENSE REPORT ON

THE TECHNOLOGY BASE AND SUPPORT OF UNIVERSITY RESEARCH

FOR THE
COMMITTEES ON ARMED SERVICES
UNITED STATES CONGRESS

1 MARCH 1985

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CHAPTER I

INTRODUCTION

The Senate Committee on Armed Services expressed concern, in a report dated May 31, 1984, "over the lack of growth in the Defense technology base over the past 2 years" and stated their belief that "the technology base programs represent our investment in future defense capabilities." Focusing on Department of Defense (DOD) support for university research, the Committee said that "DOD must do its share to maintain the excellence of our scientific infrastructure through strong support of university research." The Committee requested a report "on DOD activities and plans to support the United States infrastructure for science and engineering education and research." The Committee directed that the report "should address the role of DOD in the education and training of engineers and scientists for technologies used by DOD through (1) the support of university research, including independent research and development, (2) the interaction of defense contractors with the universities, (3) the use of fellowships, internships, and cooperative education, (4) the upgrading of university research instrumentation and facilities, and (5) the maintenance and development of technical skills in DOD laboratories. The report should also address how we, our NATO allies and Japan could work more effectively together in long term research to maintain our scientific and technical lead over the Soviet Union." This report is submitted in response to that request.

In the long run, a strong United States science and technology (S&T) base is essential for maintaining the nation's military and economic position. The DOD S&T program is a major contributor to this effort to strengthen our national defense. Some relevant achievements accomplished or progress made in the program include:

1. Early development of lasers and incorporating their unique capabilities into weapons systems; the result is unprecedented precision in navigation and targeting.

2. Early development of integrated circuits and their application to mission critical capabilities in target detection and identification as well as weapon guidance.

3. Development of aircraft technology which provides substantially improved capabilities in maneuverability, flight and fire control, and firepower.

4. Significant progress in the development and fielding of chemical warfare protection which enables combat units to better survive and fight in a chemical warfare environment.

5. Development of the carbon-carbon composite material nosetip for the TRIDENT D-5 re-entry vehicle.

The DOD total S&T Program effort in FY 1985 is about $6.0 billion, of which about $0.9 billion is allocated to Basic Research, $2.3 billion to Exploratory Development, and $2.8 billion (including $1.4 billion for the Strategic Defense Initiative) to Advanced Technology Development.

The DOD S&T Program is carried out by three performers. In FY 1984, more than half of the DOD S&T effort was performed by industry, about a third by DOD in-house laboratories, and the balance by universities. Each performer plays an important role in the overall DOD effort, and the strong interrelationships and synergisms among the three components of the scientific infrastructure yield a major return on this investment. In view of the strong interrelationship among the three performers, this report considers efforts in all three areas to identify DOD needs, existing activities that should be strengthened, and new initiatives which have been undertaken or are being considered. This report also describes the major bilateral and multilateral S&T arrangements with our allies.

Analysis of the DOD S&T Program indicates that:

- Many important S&T contributions are being made toward increasing the technological warfighting capability of defense systems.

- S&T work being performed by industry, universities, and in-house laboratories is of high quality, scientifically sound, and vital to our national defense.

The maintenance of future U.S. S&T capabilities will, however, require:

- Additional funding in several S&T areas.

- Measures to correct a decline in the supply of scientists and engineers to perform necessary defense-related research, particularly in universities and in-house laboratories.

- Upgrading of university and in-house laboratory research instrumentation and facilities to assure high quality research.

- New approaches in the contracting process to simplify interactions among government laboratories, industry, and universities involved in the S&T Program.

- Cooperation and collaboration with our allies to improve our S&T posture.

This report describes some of the programs which are under way to address these issues. In addition, the FY 1986 budget request addresses some of these concerns. Continuing Committee support of the Science and Technology Program is necessary to the nation's future defense capabilities.

CHAPTER II

DOD SUPPORT OF UNIVERSITIES

A. INTRODUCTION

Overview

The subject of this chapter is the role that universities play in sustaining and strengthening the U.S. science and technology base, the scope and nature of existing DOD programs that support universities in that role, and additional measures that DOD may take to enhance that support. Subsequent sections of this chapter will address the DOD role in the direct funding of university research (Section B), the upgrading of research instruments and equipment (Section C), and the use of fellowships and other "people-oriented" programs to encourage career choices into areas of particular importance to DOD (Section D). Specific recommendations and future plans are summarized in Section E.

Granted the importance of these issues to DOD, it must nonetheless be recognized that maintaining an adequate science and technology base is a national priority with important economic as well as military implications. Thus, DOD cannot be expected to solve the attendant problems alone. Solutions must be broadbased in nature, encompassing all relevant government agencies, the private sector, and the universities themselves. This chapter focuses, however, on the relationship between DOD and universities.

Role of the Universities

The university establishment plays a uniquely important role relative to the strength of the nation's science and technology base. The universities are the source of future scientists and engineers. In addition, the research contributions of academia to society are enormous. In the post-World War II era, universities have conducted most of the fundamental research that has spawned the technological innovations on which much of our economy and national defense are based today. Universities contribute approximately 70 percent of the scholarly papers appearing in prestigious science and technology journals. In addition to generating scientific insight and knowledge which forms the basis of future technological innovation, university research activities provide an essential environment for the development of future scientists and engineers. These activities enrich the professional experience of faculty and graduate students engaged in the training of technical manpower. Thus, support of university research produces multiple payoffs of inestimable value to society.

The success of the academic teaching and research enterprise involves a number of factors. They include a creative, dedicated faculty, sufficient laboratory and support resources, and an adequate supply of students, both graduate and undergraduate. Within the framework of these criteria, a number of challenges are associated with maintaining and/or upgrading the nation's technical education and research capacity:

o Faculty Shortages in Technical Fields: A survey conducted by the American Society for Engineering Education (ASEE) indicates an overall engineering faculty vacancy rate of 8.5 percent in 1983, with vacancy rates in electrical and computer engineering at 9.7 and 15.8 percent respectively. These shortages are primarily due to industry demand for talent in these areas. This demand tends both to decrease the number of persons seeking advanced degrees in technical fields and to lure those persons who do go on for a Ph.D. out of academe. Industry currently offers significantly higher salaries and superior laboratory equipment.

o Decline of U.S. Citizen Participation in Graduate Programs: The number of engineering doctoral degrees awarded to U.S. citizens by U.S. universities declined steadily throughout the 1970s and early 1980s, producing a net decline of 42 percent between 1968 and 1982, while the number of advanced degrees awarded to foreign nationals almost tripled during this same period. Nearly half of the engineering Ph.D.s now awarded go to foreign nationals. Little is known about the employment plans of foreign science and engineering Ph.D.s, but about half return to their home country. Whatever their plans, however, they generally cannot obtain U.S. security clearances and are not available for direct DOD employment and may be restricted as to DOD related work in universities and industry.

The decline in the number of American citizens pursuing advanced degrees can be attributed to several factors. First, as previously mentioned, marketplace demand for engineers is such that attractive job offers, providing immediate return on a student's investment in education, are luring bachelor degree recipients into industry. In addition, financial support is less available to graduate students than in the past. In 1983, the U.S. Federal government supported only 20 percent of the number of fellowships in 1968. Of those supported in 1983, only 1,600 were in engineering and science.

Finally, it must be noted that, as a result of demographic factors, the total number of 22 year olds in the U.S. will decline by approximately 17 percent by 1990. The decline in student population, already evident in many parts of the country, commensurately shrinks the pool from which future science and engineering talent can be drawn. Thus, unless student career preferences change substantially, the U.S. will graduate fewer scientists and engineers rather than the increased numbers required to maintain national technological competitiveness.

o Decline of University Research Laboratories: Estimates ranging up to $2 billion have been proposed as a requirement for replacing obsolete university research instrumentation. Laboratory facilities, especially instrumentation necessary to conduct research aimed at expanding the U.S. technology base, are becoming increasingly expensive. Establishing and maintaining these facilities is a very costly proposition for such equipment items as advanced supercomputers, large particle accelerators, various types of analytical instrumentation, imaging devices, and automated design and manufacturing hardware. Such equipment, nonetheless, is crucial for the conduct of meaningful research in important areas of science and engineering, and for the training of students.

DOD Support for Universities

As one of the first Federal agencies to recognize the essential role that U.S. colleges and universities play in the maintenance of U.S. technological leadership, DOD has maintained a strong relationship with the academic community; this relationship predates World War II. Since technological leadership is an essential component of military superiority, DOD has a major stake in maintaining the strength of U.S. science and technology.

o Direct Funding of University Research: U.S. universities are a major factor in DOD technology base activities. Approximately one half of DOD's Basic Research (6.1) is performed at universities ($405 million out of a total of $840 million in FY84). Support for universities is not limited to funding for Basic Research. As an additional important benefit, the resulting university research programs are a major factor in addressing the problems of the universities that were discussed in Section A.2. By providing the opportunity to perform fundamental research at the forefront of science and engineering, university research programs help to create a professional environment that can attract and retain faculty and students. Past studies suggest that, on average, each $1 million of research program provides full or partial financial support for approximately 10-15 graduate students. On that basis, DOD provided financial assistance for over 4000 graduate students through its university research programs in FY84. As will be shown in Section C of this chapter, roughly $75 million worth of instruments and equipment were purchased by universities in FY84 through DOD research programs (counting a $30 million per year Defense University Research Instrumentation Program (DURIP) discussed below).

The DOD-university relationship has received strong emphasis during the last decade. In constant dollars, DOD funding for the performance of basic research at universities grew at an average annual rate exceeding 9 percent during the period 1975 to 1984. This is far better than funding for DOD technology base activities as a whole, which is still below 1965 levels in real terms as noted by Secretary Weinberger's memorandum to the Services dated August 9, 1984. As in the past, universities can be expected to compete effectively for future growth in DOD technology base funds. In the memorandum referred to above, Secretary Weinberger requested real growth for the technology base in the Defense Guidance for the FY 1987-91 Five Year Defense Plan. DOD continues to support that position. A more detailed discussion of direct funding of R&D at universities is provided in Section B of this chapter.

o University Research Instrumentation: DOD recognized the nature of the university research instruments and equipment problem well before formal studies were initiated. As suggested above, the fraction of university research contracts devoted to the purchase of instruments and equipment has been increasing--reaching approximately $45 million per year in 1984. In addition, specially targeted funds of $30 million per year are provided for large equipment purchases through the Defense University Research Instrumentation Program (DURIP). The availability of modern instruments and equipment improves the quality of university research and enables universities to compete more effectively with industry for scientists and engineers. DOD will continue to address instrumentation needs through its research contracts and through special programs such as DURIP and the newly proposed "University Research Initiative" program elements discussed below. However, DOD cannot and should not address this problem alone. In view of the scope and magnitude of the problem, it must be addressed over a period of years in an interagency-private sector context. DOD instrumentation programs are discussed in Section C of this chapter.

o <u>University Research Facilities:</u> Although concern has been expressed about the condition of university research facilities (e.g., laboratory buildings), the dimensions of the problem have not been quantified. DOD is currently assessing the nature and scope of this problem. Results will be made available to the Committee as they are received. Once again, this is a problem which must be addressed over a period of years in a national context.

o <u>Education Programs:</u> The three Services have initiated a number of special programs designed to attract exceptional candidates to graduate study and to university faculty careers in areas of science and engineering of particular interest to DOD. These programs include graduate fellowships, summer faculty programs, special faculty chairs, a newly established Navy Young Investigators program, and programs to enhance professional interaction between university scientists and engineers and their colleagues in DOD laboratories and in industry. When considered in the context of stable growth for the technology base, increased availability of modern equipment in university laboratories, and the growing emphasis on similar programs at other federal research organizations, these "people-oriented" DOD initiatives represent a significant supplemental incentive to attract exceptional students and faculty to areas of interest to DOD. Funding levels for these programs will be increased with the availability of funds through the "University Research Initiatives" discussed below. Other relevant special DOD programs are designed to attract more women and minorities to science and engineering research, and to provide incentives for high school students to consider technical careers. Some of these special programs are discussed in greater detail in Section D of this chapter.

o <u>"University Research Initiative" Program Elements</u>: In FY86 DOD plans to establish new research program elements that will be focused exclusively on the DOD/university relationship. Total proposed funding for the new program elements is $25 million in FY86, and $50 million in FY87. Additional growth is anticipated in future years. Each of the Services and the Defense Advanced Research Projects Agency (DARPA) will implement programs within these program elements to meet the priorities of their specific relationships with the academic community. Although the specific mix will vary from Service to Service, graduate fellowships, support for young investigators, purchase of research instrumentation, and support of special research programs will be included in the total DOD program for these program elements.

o <u>DOD/University Advisory Groups</u>: DOD has long recognized the value of the academic community as a source of expert advice. The Department maintains communications with people in the academic community, as individual consultants and as members of numerous advisory committees, on programmatic issues at all levels. To insure more effective communication with the academic community, specifically focused on issues at the policy level, DOD established the DOD/University Forum in 1983. The Forum has provided a mechanism for continuous dialogue between DOD and the academic community on issues of mutual interest. One significant, direct outcome of the Forum's activities during the past year was the establishment of a policy on the transfer of scientific information. The resulting clarification of DOD policy establishes an appropriate balance between the conflicting imperatives of national security and open scientific communications.

B. DIRECT FUNDING OF UNIVERSITY RESEARCH

The Senate request for this DOD report on the technology base included the observation that "DOD investment in the technology base dropped by 40 percent from the mid-1960s to mid-1970s and today remains more than 30 percent below the mid-1960s level in real terms." This general pattern is illustrated in Figure B.1 which shows the history of DOD funding for basic research (6.1) since 1962. The corresponding funding history for exploratory development (6.2) is shown in Figure B.2.

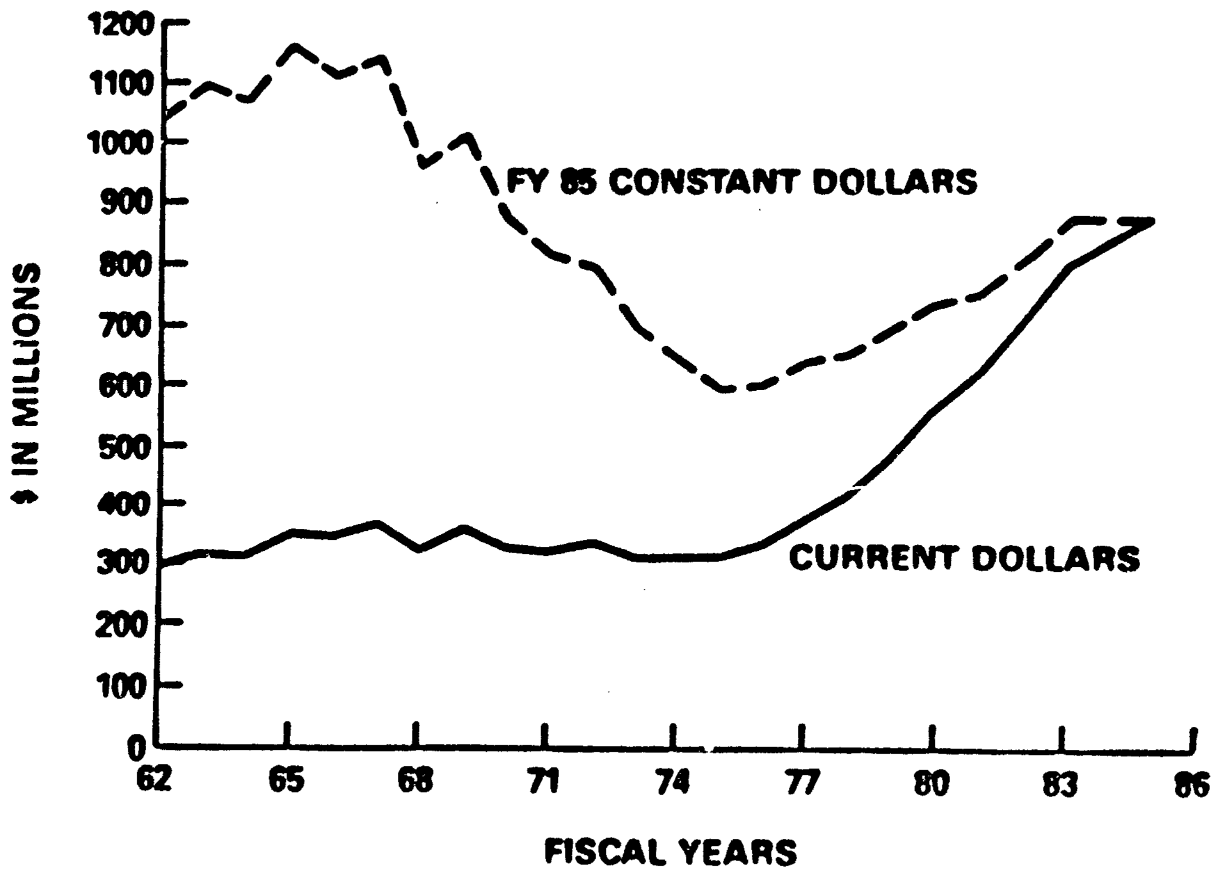
During the past decade, DOD has taken major steps to reverse the past impact of the relative neglect of the technology base. As Figures B.1 and B.2 illustrate, funding in current dollars for both components of the technology base grew significantly during the late 1970s and early 1980s; nevertheless, neither component has returned to 1965 levels of support in real terms. In fact, in real terms, funding for exploratory development has been virtually constant for over a decade. In a memorandum to the Services dated August 9, 1984, Secretary Weinberger noted these facts and indicated that the Defense Guidance for the FY 1987-91 Five Year Defense Plan would request annual real growth in both components of the technology base. DOD still supports that position.

University research has been a major component of the growth in DOD technology base activities during the past decade. Table B.1 exhibits DOD 6.1 Research funds spent at or budgeted for universities by the Army, Navy, Air Force, and DARPA for the years FY74-86. Note that during the period FY75 to FY84 DOD spending for 6.1 Research at

FIGURE B.1

DOD SCIENCE AND TECHNOLOGY FUNDING TRENDS

CURRENT AND CONSTANT DOLLARS RESEARCH (6.1)

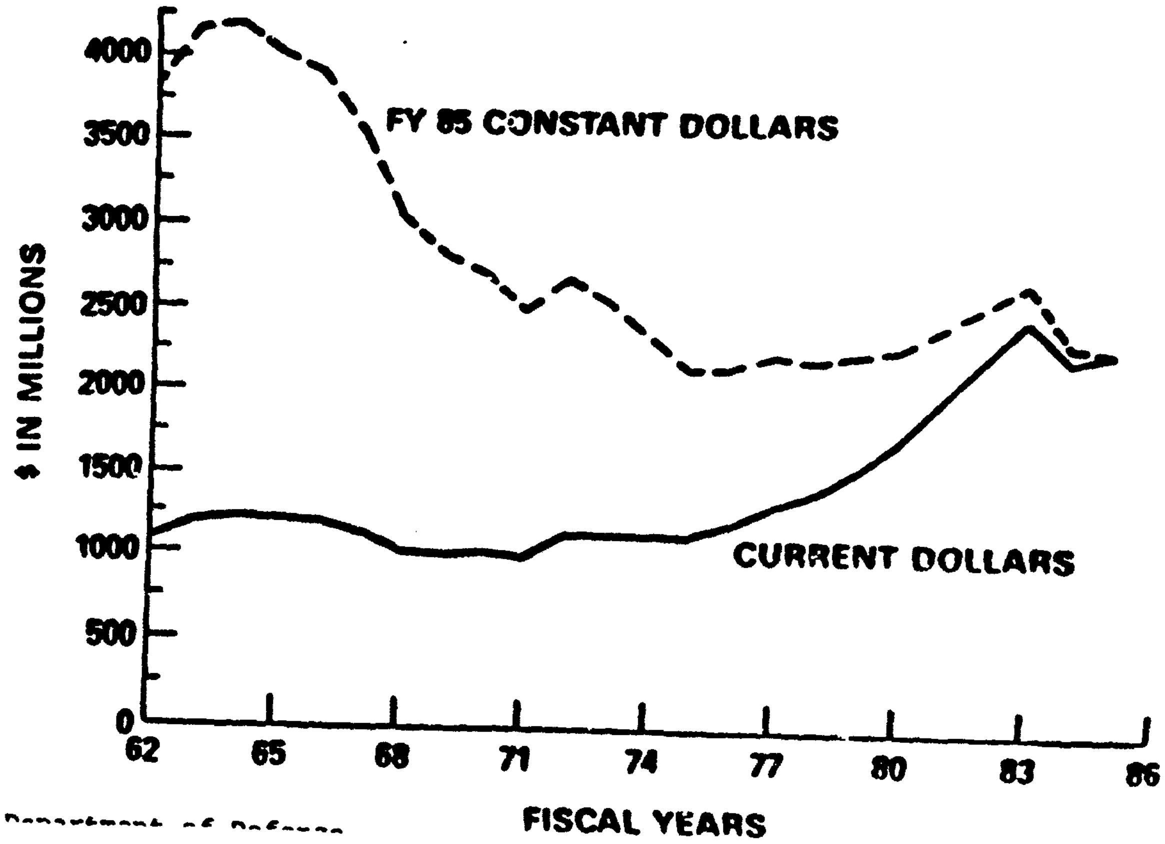


SOURCE: Department of Defense

FIGURE B.2

DOD SCIENCE AND TECHNOLOGY FUNDING TRENDS

CURRENT AND CONSTANT DOLLARS EXPLORATORY DEVELOPMENT (6.2)



SOURCE: Department of Defense

TABLE B.1

DEPARTMENT OF DEFENSE FUNDING FOR UNIVERSITY BASIC (6.1) RESEARCH, FISCAL YEARS 1974-86
(In millions of dollars)

	FY 74		FY 75		FY 76		FY 77		FY 78		FY 79		FY 80	
Service	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real
ARMY	13.7	27.9	13.4	25.0	19.0	33.7	23.7	39.6	28.1	43.8	32.0	45.9	38.1	50.1
AIR FORCE	23.2	47.3	22.9	42.6	28.2	50.0	41.0	68.6	49.5	77.1	46.4	66.6	55.3	72.7
NAVY	45.5	92.7	47.0	89.2	64.2	113.8	62.7	104.8	70.8	110.3	86.4	124.0	100.2	131.7
DARPA	21.9	44.6	19.4	36.1	19.1	33.9	18.7	31.3	17.9	27.9	21.0	30.1	19.8	26.0
TOTAL	104.3	212.4	103.6	192.9	130.5	231.4	146.1	244.3	166.3	259.0	185.8	266.6	213.4	280.4

	FY 81		FY 82		FY 83		FY 84		FY 85*		FY 86*	
Service	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real**	Current	Real**
ARMY	46.5	55.9	56.1	63.5	71.4	77.7	80.6	84.6	83.8	83.8	87.9	83.8
AIR FORCE	63.4	76.2	71.5	81.0	90.3	98.3	112.1	117.6	119.1	119.1	135.0	128.7
NAVY	115.0	138.2	142.3	161.2	152.2	165.6	158.1	165.9	176.1	176.1	198.8	189.5
DARPA	27.3	37.8	39.4	44.6	46.4	50.5	53.9	56.6	42.7	42.7	43.4	41.4
TOTAL	252.2	303.1	309.3	350.3	360.3	392.1	404.7	424.7	421.7	421.7	465.1	443.4

* Projections
** Forecast for inflation is based on CBO projection
SOURCE: Army Deputy Chief of Staff Research Development and Acquisition, Office of Naval Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, (Constant 1985 Dollars Calculated using GNP Implicit Price Deflator)

universities grew at a real annual rate of 9 percent--higher than the annual growth of the total DOD 6.1 Research program.

Table B.1 shows only the DOD Research (6.1) funds going to universities. A similar break out of the university component of DOD Exploratory Development (6.2) funds is not readily available. To provide a point of reference, in FY83 a total of $102.3 million in DOD Exploratory Development (6.2) contracts went to universities as compared to $360 million for Research (6.1) contracts and grants. It should be noted that DOD funding for universities is not limited to Research and Exploratory Development.

DOD sponsors research and development at universities to ensure the advancement of fundamental knowledge that is necessary, in the long run, to maintain technological superiority. However, as will be noted in Sections C and D of this chapter, university research programs have other important impacts that have a significant effect on the future supply of scientists and engineers by attracting and retaining potential faculty and students, i.e., support for fundamental scholarly research, purchase of modern instrumentation, and financial support for thousands of graduate students.

C. INSTRUMENTATION

Background

Instrumentation is an essential element of modern research. Modern instruments with qualitatively superior capabilities for analysis and measurements can open new fields of scientific inquiry. In many scientific areas, access to the most advanced scientific instrumentation determines in large measure the extent to which scientists can work at the cutting edge of their field.

There has been a growing realization among the scientific and university communities, and in state and Federal government agencies and the Congress, that the condition of research instrumentation in U.S. universities declined significantly during the 1970s. The Association of American Universities (AAU) in a report to the National Science Foundation (NSF) in June 1980 concluded that the equipment being used in the top ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories, an additional factor in the attraction of potential faculty to industry.

A more recent survey by the NSF emphasizes this point. Data for the research instruments surveyed by the NSF were collected from a stratified probability sample of 43 universities selected from the 157 largest academic R&D performers. Inventories for all existing research equipment were obtained from institutions' central record-keeping systems and were sent to department heads for verification. More than 90 percent of both department heads and investigators responded. According to the survey, 25 percent of U.S. academic research equipment is classified as obsolete by the scientists who use it, whereas only 16 percent is characterized as being state-of-the-art. Results of the survey, based on 22,300 items in a 1982 research equipment inventory in computer and physical sciences and engineering, are summarized below:

Status	Age	Purchase Price
2% not in use	45% 1-5 years	58% $10,000-$24,999
16% state-of-the-art	20% 6-10 years	31% $25,000-$74,999
26% obsolete	31% over 10 years	11% $75,000-$1M
56% other		

The NSF study provides a more detailed breakdown by research area.

In terms of its capability to enable investigators to pursue their major research interests, department heads rated the adequacy of their research equipment as: excellent--8 percent; adequate--46 percent; and insufficient--46 percent. More than 90 percent reported that "important subject areas" of research could not be performed in their units because of lack of needed research instrumentation. Thus, the state of university research instrumentation represents a national problem which deserves serious attention by government, private industry, and the university research community. The gap between the present university research instrumentation capability and that required to ensure maximum productivity by creative and innovative researchers has been estimated to be at least a billion dollars.

The instrumentation problem has been building for a period of 10 to 15 years. It reflects a combination of economic factors and funding patterns:

- The cost of equipment has risen considerably faster than inflation.
- The system of one to three year contracts in the $50,000 to $100,000 per year range with individual investigators tends not to lend itself to the purchase of equipment costing more than $50,000.
- Rapid advances in instrumentation technology are rendering research equipment obsolete at an ever increasing rate.

DOD Instrumentation Programs

Through its contacts with university researchers, DOD became aware of the instrumentation problem well before formal studies of the situation were initiated. DOD has encouraged investigators to include more of their equipment needs in proposals and emphasized that DOD does not set artificial limits on the amount of money that could be requested for instrumentation. This approach has been adequate to deal with equipment needs up to the $50,000 range. However, there was a clear need for new money dedicated to the purchase of some of the more expensive items required to modernize university laboratories. These funds were provided in FY83 through the Congressionally approved DOD-University Research Instrumentation Program (DURIP).

DURIP provides $150 million over five years for university research equipment. Each of the three Services is programmed to spend $10 million per year. To date, $90 million has been spent on 652 awards going to 152 institutions in 47 states and Washington, D.C., Guam, and Puerto Rico. DURIP is having a major impact on the equipment needs of researchers doing work of interest to DOD. It will not, however, solve the whole university instrumentation problem. In the first year of DURIP, DOD received 2,500 proposals representing requests for $646 million worth of equipment. While some of these requests were for equipment to support research in areas not funded by DOD the first year response is nevertheless an impressive qualitative measure of the needs of the universities.

As already mentioned, DURIP is the most visible, but not the only, DOD response to the university instrumentation problem. In addition, each of the Services and DARPA have encouraged current and prospective contractors to make their equipment needs known so that many of the less expensive items can be purchased as an integral part of research program funding:

- The percent of the Army Research Office (ARO) contract program devoted to instrument purchases has increased steadily over the last decade so that in FY85 such purchases will represent approximately $6 million of the ARO contract research program.

- University related equipment purchases associated with the Office of Naval Research's Contract Research Program grew from $11.2 million in 1979 to $16.6 million in 1984.

- During the decade from 1975 to 1985, equipment funding by the Air Force Office of Scientific Research, during the normal course of its sponsored research program, increased from $2 million to $8 million per year.

- In general, 10 to 20 percent of DARPA's university program funds have been utilized for equipment. In 1981, DARPA initiated a modernization program targeted on obsolete equipment and the need for greater computational power. From 1981 to 1984, equipment purchases by universities using DARPA funds increased from $6.7 million to $16.8 million per year.

In certain cases, where the equipment necessary for major research efforts has been costly, specific provisions have been made for extraordinary purchases. Examples include the purchase of large main frame computers, semiconductor processing lines, molecular beam epitaxy and analysis chambers and ARPANET computational and communication facilities by DARPA, and an ongoing Office of Naval Research program to refurbish selected research vessels.

In FY84, in addition to the $30 million of special DURIP purchases, the three services and DARPA purchased over $45 million worth of research instruments and equipment for universities in connection with their ongoing research contracting activities.

D. EDUCATION PROGRAMS

Background

The ability of the United States to maintain superiority in broad areas of science and technology will largely depend on how well universities and colleges are able to recruit and train new scientific and engineering talent. Declining numbers of doctoral degrees awarded to U.S. citizens, coupled with the shortage of faculty in technical fields and the lure of industry employment, make the universities' task a difficult one.

The U.S. defense industry is a major employer of the scientists and engineers trained by U.S. universities and colleges. According to a recent National Science Foundation (NSF) study, the percent of U.S. engineers employed in defense activities will increase from 12 percent in 1982 to 15 percent in 1987. In 1982, DOD alone employed 105,000 engineers and scientists (3.6 percent of the national total). The NSF study projects rapid growth and shortages exceeding 10 percent of the workforce (by 1987) in disciplines particularly important to DOD: aeronautical engineers, computer specialists, and electrical/electronic engineers. This general conclusion is reinforced by projections of the American Electronics Association that predict an annual growth rate of 10.6 percent in the demand for electrical engineers through the late 1980s and a 16.5 percent growth rate in the demand for computer engineers.

Granted the importance of these trends to DOD, it must be emphasized that DOD and the defense industry are important but not dominant factors in the employment of scientists and engineers. Solutions must involve all relevant government agencies and the private sector.

The prospects for attracting greater numbers of outstanding students into careers in science and engineering in DOD are clouded by a number of important factors:

- Due to demographic factors, the number of students graduating annually from U.S. high schools during the 1980s is expected to drop significantly (approximately 17%). Together with the decreasing percentage of students studying mathematics and science, this trend is likely to have a major effect on the pool of young people who can be attracted into technical careers.

- High vacancy rates are reported for high school teaching positions in mathematics and the physical sciences. The number of people preparing to teach in these areas has decreased markedly.

- The number of Ph.D.s in engineering awarded to U.S. citizens by U.S. universities declined steadily throughout the 1970s and early 1980s, with a net decline of 42 percent between 1968 and 1982. Nearly half of all engineering Ph.D.s now go to foreign nationals. As indicated earlier, foreign engineering Ph.D.s, even if they remain in the U.S., generally cannot obtain U.S. security clearances and are thus not available for direct DOD employment. Reasons for the decline in U.S. citizens receiving graduate degrees include the lure of industry with existing pay differentials, the increasing cost of graduate school, and the decline in federal financial assistance.

DOD Education Programs

During the past decade, DOD has initiated numerous "people-oriented" programs designed to increase the supply of qualified technical personnel, both uniformed and civilian, and to attract exceptional candidates into careers in areas of particular importance to DOD. The complete set of programs is extremely diverse, ranging from secondary school level through undergraduate and graduate school. Some are designed for postgraduates and university faculty. Some relevant DOD programs are listed in Table D-1, including a number of programs that are supported with funds other than RDT&E funds. Additional information on selected programs will be provided below.

It is important to recognize that the formal programs listed in Table D-1 and those discussed below are supplemental to DOD's basic research programs. In addition to meeting important DOD technology base requirements, the direct funding of university research represents DOD's largest single education program. For example, a Navy study conducted in 1980 indicated that the Office of Naval Research (ONR) supported an estimated 2,200 graduate students (fully or partially) through its 6.1 contract research program. This study and similar estimates by others suggest that, on average, a million dollars of 6.1 university research funding provide financial support for approximately 10-15 graduate students. On that basis, the DOD university research program provided financial assistance for well over 4000 graduate students in 1984. In addition, the combination of research contracts and instrumentation programs provides a university research environment that is essential to retain university faculty and to attract graduate students.

DOD reaps several benefits from its supplemental support of science and engineering education. First, the programs attract highly-qualified students and support their training in areas of interest to DOD. Second, fellowship support increases the number of doctoral students who

TABLE D.1

DOD SCIENCE AND ENGINEERING EDUCATION PROGRAMS*

SPONSOR	PROGRAM TITLE
ELEMENTARY & SECONDARY	
ARMY	Junior Science and Humanities Symposium Science and Engineering Fair Program Research and Engineering Apprenticeships Uninitiated Introduction to Engineering International Mathematical Olympiad Armed Forces Orientation in Engineering
NAVY	Research and Engineering Apprenticeships Pre Co-Op Program Navy Science Awards Program
AIR FORCE	Precollege Technical Orientation Research and Engineering Apprenticeships Uninitiated Introduction to Engineering
UNDERGRADUATE	
ARMY	ROTC - Hi Tech Scholarship Emphasis Co-Op Lab Employee Educational Program
NAVY	ROTC - Science and Engineering Program Co-Op Education Program Federal Junior Fellowship Program
AIR FORCE	Airman Education and Commissioning Program ROTC - Science and Engineering Scholarship Emphasis (85% for S&E Students) AF Institute of Technology Undergraduate Engineer Conversion Program College Senior Engineering Program (CSEP)
GRADUATE	
ARMY	Graduate Contract Research Programs Graduate Programs in computer science, electronics, modern optics, hypersonic aero-mechanics and aero-dynamics, and biogenetic engineering Graduate Programs at Centers of Excellence in Rotary Wing Technology

* Funded from various DOD sources, not limited to RDT&E funds. Programs which support the voluntary education of uniformed personnel are not included.

TABLE D.1 (Continued)

NAVY	Office of Naval Research-Graduate Contract Research Program Co-Op Education Program Graduate Programs in electrical engineering, computer sciences, naval architecture, applied physics, material sciences and mechanical and aerospace engineering Military Graduate Education Programs
AIR FORCE	Graduate Contract Research Programs Graduate Programs in thermionic engineering, composite structures, aircraft propulsion and manufacturing sciences
SPECIAL PROGRAMS	
ALL SERVICES	Historically Black Colleges Summer Faculty Research and Engineering Program Equipment Grants/Research Instrumentation Post Graduate Fellowships
ARMY	Summer Associateship for High School Science and Mathematics Faculty
NAVY	ONR Young Investigators Program

then have the potential to train other students. Third, training programs provide a pool of recruits for the various DOD RDT&E programs. Finally, the programs provide a variety of intangible benefits ranging from the expansion of professional contacts and rapport with the various DOD laboratories to the generation of interest and excitement in science and mathematics at the elementary and secondary school levels. Highlights are provided below for selected programs.

HIGH SCHOOL APPRENTICESHIP PROGRAM

DOD established the DOD Science and Engineering Apprenticeship Program for High School Students in 1981 with the objective of encouraging and supporting careers in science and technology. The program has three major purposes: one, to stimulate stronger interest in careers in science and engineering among high school students; two, to establish individual student/mentor relationships between students and active researchers; and three, to strengthen the nation's efforts to recruit and sustain careers in science and engineering, consistent with affirmative action program goals and objectives. Although the apprenticeship program applies most directly to DOD laboratories, it can also be used by the service research offices through their contract-supported principal investigators at universities.

SELECTED ARMY EDUCATION PROGRAMS

The Army has programs in science, mathematics, and engineering education at the secondary, undergraduate, graduate, and postgraduate levels.

Pre-College Education Programs. (i) The Junior Science and Humanities Symposium (JSHS) Program exposes 7,500 secondary students each year to leading scientists in the academic, industrial, and government communities. (ii) 60,000 students annually participate in more than 280 regional, state, and International Science and Engineering (ISEF) Fairs. (iii) Eight talented students are selected competitively from over 400,000 high school participants to represent the U.S. at the annual International Mathematical Olympiad (IMO). (iv) The Uninitiated Introduction to Engineering (UNITE) program provides a select group of socially - and economically - disadvantaged high school students with four weeks of summer instruction and guidance by cooperating universities and Army laboratories. (v) The Research and Engineering Apprenticeship Program (REAP) can extend over several summers and offer mentor/apprentice training for disadvantaged youngsters by university professors. (vi) An intensive, four-week program involving digital logic, microprocessors, robotics, and programming is available in Computer Related Engineering and Science Studies (CRESS).

Undergraduate Educational Programs. The Army's Reserve Officer Training Corps (ROTC) program includes 12,000 students at over 300 universities; recent selections have emphasized science, mathematics, and engineering. Also, the Army has a very active co-op work/study arrangement with many colleges and universities.

Graduate Level Educational Program. Over 800 research contracts with universities throughout the United States support, as a byproduct, many graduate students working on the contracts. In addition, last year, the Army awarded 35 graduate fellowships in computer science, electronics, modern optics, hypersonic aeromechanics and aerodynamics, and biogenetic engineering under the Army Fellowship Program.

Special Educational Programs. Seventeen historically black colleges (HBC) are involved in a special Army effort to sponsor mathematics, engineering, and science research at HBCs; about $1.4 million per year is involved. The Summer Faculty Research and Engineering Program (SFREP) offers 10-week summer appointments in Army laboratories to selected university faculty members; 24 Army laboratories participate. The Army has a similar program for high school science and mathematics faculty that involved 90 teachers in first summer of the program.

Postdoctoral Program. Working with the National Academy of Sciences, the Army has about 55 National Research Council Fellows working in several Army laboratories on postdoctoral research. This program is available to new doctoral graduates as well as to more senior researchers at colleges, universities, non-profit research institutes, etc. The program fosters interaction between Army and civilian scientists and engineers, and it has resulted in Army recruitment of many capable young researchers.

SELECTED NAVY EDUCATION PROGRAMS

The Navy supports science and engineering education at all levels. Several of these programs are run by or in conjunction with Navy laboratories because of their direct need for highly trained personnel.

At the pre-college level, the Navy has programs for hiring science and engineering apprenticeship students at laboratories in the summer. ONR encourages university contractors to involve high school students on research projects. In FY 1983, 335 students were supported under these programs. In addition to participating in regional and state science and engineering fairs, the Navy offers scholarships and other awards in the Navy National Science Awards Competition and the International Science and Engineering Fair.

At the college undergraduate level, the Navy supports three programs: the ROTC Science and Engineering Program, the Co-op Education Program, and the Federal Junior Fellowship Program. In FY 1983, these programs had approximately 7,300 participants.

The Navy supports several significant educational programs at the graduate level. These include the ONR Graduate Fellowship Program, the Co-op Education Program, and the Military Graduate Education Program. The ONR Graduate Fellowship Program is directed toward increasing the supply of U.S. citizens trained in areas of science and engineering of particular importance to current and future naval technology. Started in FY 1982, this program currently supports 40 new fellows per year, who pursue doctoral studies in electrical engineering, computer science, naval architecture, applied physics, material science, mechanical and aerospace engineering, mathematics, and oceanography. Funding for this program is planned to grow to over $4.5 million by FY 1989, thereby enabling the selection of 50 new ONR fellows per year. This represents a 20 percent increase over the present level.

The Navy supports postdoctoral training at Navy laboratories and under research contracts at universities. The Navy awards Postdoctoral Cooperative Research Associateships through the National Research Council. These associateships can be used at the Naval Research Laboratory (NRL), Washington, D.C. and the Naval Ocean Research and Development Activity (NORDA), Bay St. Louis, MS. These competitive awards provide opportunities for doing basic and applied research on-site at NRL or NORDA. A program sponsored by the Office of Naval Technology provides similar opportunities for thirty postdoctoral research fellows each year at the other Navy laboratory centers.

In addition to student support, the Navy provides faculty support. Under the Summer Faculty Research Program, science and engineering faculty members from universities and colleges spend ten weeks in the summer conducting research at Navy laboratory centers. For the last three years, over one hundred university faculty members have entered this program each summer. Participants work with professional peers on research tasks of mutual interest. Follow-up programs have been found to occur between the laboratories and the faculty members in about 30 percent of the cases. A second program supports research chairs at the U.S. Naval Academy, the U.S. Naval Postgraduate School, the Massachusetts Institute of Technology, and the University of Michigan. The Navy also finances visiting professorships to the U.S. Naval Academy and the U.S. Naval Postgraduate School.

ONR plans to initiate a new program in FY 1985 to identify and support exceptional young investigators who are in tenure track positions at U.S. universities. The ONR Young Investigator Program is designed to encourage younger researchers to take an active role in naval research. ONR will invest $2.0 million in this program in FY 1985.

In addition to its formal educational programs, the Navy also has the Historically Black Colleges (HBC) Council. The Council is an officially established ONR body whose primary purpose is to facilitate relationships between HBC institutions and ONR that may eventually lead to greater HBC participation in the ONR Contract Research Program (CRP). As a result of this and other efforts, ONR spent $2.4 million with HBCs in FY 1984.

SELECTED AIR FORCE EDUCATION PROGRAMS

The Air Force is supporting science and engineering education through officer commissioning and graduate education programs, civilian personnel programs, and a number of special programs associated with basic research.

Under its officer commissioning programs, in FY 1985 the Air Force will provide 7,500 ROTC scholarships, of which 85 percent are for S&E students. It will also enroll about 400 airmen in the Airman Education and Commissioning Program, of which about 90 percent will be S&E students, and 75 students in the College Senior Engineering Program. In FY 1985, about 525 officers will enter graduate S&E programs.

The Air Force Laboratories, Centers, and Product Divisions also support programs to: (1) introduce high school students to Air Force technical careers; (2) employ undergraduate S&E students in co-op, stay-in-school, and summer hire programs; and (3) support the technical upgrading of civilian S&E employees through short-term and long-term full time training programs.

At present, about 60 percent of the Air Force basic research program is under contract at universities. This research supports an estimated 1,000 to 1,200 graduate students through research assistantships. In addition to this general support, AFOSR and the Air Force laboratories provide research and educational opportunities for graduate students, post doctoral scientists and engineers, and university faculty through special programs that support research on problems of interest to the Air Force.

The Air Force Office of Scientific Research (AFOSR) supports four graduate student assistantship programs that are focused on research areas of critical interest to the Air Force. The Air Force Thermionic Engineering and Research Program (AFTER) is focused on microwave tube research, a technology that electrical engineers supporting the vast consumer electronics industry have largely vacated. The Advanced Composite Structures Program is aimed at attracting students to research in composite structures and composite mechanics. The Air Force Research in Aircraft Propulsion Technology Program (AFRAPT) has the objective of attracting students to research in aircraft propulsion technology. The Manufacturing Sciences Program has the objective of attracting students to research in manufacturing techniques associated with aerospace vehicle assemblies. Total funding for these four programs increased from $2.5 million in FY 1982 to $4.44 million in FY 1985.

AFOSR supports two programs which bring university faculty members and graduate students into Air Force laboratories for ten weeks during the summer. The Summer Faculty Research Program (SFRP) is designed to develop the basis for continuing research of interest to the Air Force at the faculty member's institution. In addition to the ten week summer research program, funding is also provided to allow about 50 percent of the researchers (on a competitive basis) to continue the research at his or her home institution. The Graduate Student Summer Support Program (GSSSP) allows outstanding graduate students to spend ten weeks at an Air Force laboratory conducting research while accompanying faculty members selected under the SFRP. Funding for these programs increased from $1.5 million in FY 1982 to $4.4 million in FY 1985.

The Air Force supports several programs which allow postdoctoral scientists and engineers to spend a year conducting research at Air Force laboratories on problems of their own choice that are compatible with research interests of the sponsoring laboratories. The Air Force Systems Command/National Research Council Resident Research Associateship Program and the University Resident Research Program are supported by AFOSR but with researchers placed at various participating laboratories. The Air Force Geophysics Laboratory and the Air Force Weapons Laboratory also support, respectively, the Geophysics Scholar Program and the Weapons Laboratory Scholar Program within their own laboratories. Total funding for these programs increased from $1.6 million in FY 1982 to $2.9 million in FY 1985.

AFOSR is engaged in a special initiative utilizing workshops and focused advertising to make Historically Black Colleges (HBCs) aware of opportunities in Air Force research and development, and to recruit faculty members and graduate students from HBCs for participation in the SFRP and GSSSP. In addition, under a grant from AFOSR, the Tuskegee Institute is conducting a summer research apprenticeship program for minority high school students.

E. RECOMMENDATIONS AND FUTURE PLANS

Funding of University Research

Significant real growth of the DOD technology base is required to ensure the advancement of fundamental knowledge necessary, in the long run, to maintain military and economic parity through technological superiority. It must be noted that funding for university research also addresses many of the problems associated with the future supply of scientists and engineers by creating a more attractive academic environment for both faculty and students, providing financial assistance for graduate students, and supporting the purchase of modern instrumentation.

- The Congress should authorize and appropriate the President's FY 1986 budget amounts for the DOD technology base at the requested level.

- Congressional approval for the FY 1986 budget should include the establishment of "University Research Initiative" program elements, with funding at $25 million in FY 1986, devoted exclusively to university programs.

- The current Defense Guidance specifies real growth for the Research and Exploratory Development programs for the years 1987-1991. This growth should be viewed as the minimum growth rate for the direct funding of R&D that is required to restore the health of the technology base. Additional funds should be provided to exploit technological opportunities and to support special programs that supplement and leverage the direct funding of research.

- Funding for the new "University Research Initiative" program elements should be increased to a total of $50 million in FY 1987. DOD should seek additional growth in future years.

- Additional funding beyond the base program described above, if available, would be used by the Services and DARPA in areas that would provide significant leverage for the base level of DOD research funding. To give but one example, the conduct of research at the frontiers of science and engineering requires access to the most advanced numerical and symbolic computational facilities. Providing DOD contractors with access to such facilities would significantly increase their productivity in many key research areas.

Research Instrumentation

- As documented in Section C, in addition to the specially targeted $30 million per year Defense University Research Instrumentation Program (DURIP), a very significant fraction of the funds provided to universities through DOD research contracts and grants is targeted for the purchase of research instruments and equipment (roughly $45 million in FY 1984). DOD will continue to emphasize such purchases as an integral part of its contract research program.

- If approved by the Congress, the purchase of research instruments, either directly or through special research programs, will be one of the potential uses for funds in the new "University Research Initiative" program elements.

- DOD will continue its highly successful DURIP program to update university research instrumentation. Funding for this program is currently scheduled to expire after FY 1987. The magnitude of the response to the DURIP program has confirmed the perception that there is a substantial need for modern instruments in university research laboratories. DOD cannot and should not address this problem alone. The problem should be addressed in an interagency context.

Research Facilities

- DOD has an obvious interest in the condition of the research facilities available to the universities who play an essential role in DOD technology base programs. A separate study is currently under way to determine the nature and scope of this problem for DOD contractors. Preliminary studies conducted by others suggest a problem of great magnitude. Once again, DOD cannot and should not address the problem alone. The need for a multi-year, interagency approach is even greater in the case of facilities.

Education Programs

- As documented Section D, the DOD Services support a variety of programs designed to attract future scientists and engineers at all levels, ranging from high school to postgraduate study. Additional programs have been established to attract bright young scientists to academic careers and to encourage professional interaction between university scientists and engineers and their colleagues in DOD and industrial laboratories.

CHAPTER III

DOD IN-HOUSE LABORATORIES

A. INTRODUCTION

This chapter addresses factors essential to the effective performance of the Department of Defense in-house laboratories. Its aims are threefold:

- To ensure a current understanding of the roles and posture of the laboratories.
- To address representative issues critical to the vigor of these laboratories.
- To highlight approaches the DOD is using to better ensure the maintenance and development of technical skills in its laboratories.

The perspective is one of overview; the topics are highly selective. Individual laboratories are not discussed. Resource breakouts are kept to a minimum. The objective is to provide information for the Congress in an orderly form to highlight areas of action conducive to ensuring a vigorous defense science and technology community.

B. UNDERSTANDING THE LABORATORIES

Understanding the DOD laboratories is an essential part of actions to address current and future defense capabilities. From this understanding can come change which will assist the laboratories in meeting their vital roles. The current atmosphere of reduced U.S.

direct involvement in military conflicts offers an opportunity to introduce improvements into the laboratories with minimum disruption of critical activities. The high stakes involved in our international technological markets and in the national security competition with the Soviet Union make it essential that increased attention be given to:

- Better ensuring the relevance and quality of the work in the laboratories.
- Improving staff and their facilities and equipment.
- Maintaining and improving the quality of technical leadership and management of these laboratories.
- Providing this leadership the authority and flexibility to effectively manage their resources.

C. PROFILE

There are approximately 72 DOD in-house laboratories, some large, some small, performing work in the physical, life, and behavioral sciences in support of military and civil works programs of the DOD. They constitute a large investment of dollars and manpower. The acquisition cost of real property and equipment exceeds $4.0 billion. Some 27,500 scientists and engineers conduct the diverse activities of the laboratories. An annual cash flow greater than $7.9 billion is involved, with nearly two-thirds of that being research and development. About 40 percent of these R&D funds are retained by the laboratories to carry out work directly with their own personnel, the remainder being contracted largely to industry and universities. The non-R&D portion of the laboratories' funds are predominantly procurement monies that are used to achieve first acquisition of material systems and associated procurement support activities.

D. ROLES

The DOD in-house laboratories have become increasingly important to DOD RDT&E and Procurement programs. Recent emphasis in these areas increases the cruciality of their performance. As major participants in the technology base and in the systems development and acquisition process, the laboratories must undertake workload to respond to national need and programming to:

- Direct substantial R&D effort toward the longer term technological opportunities and deficiencies--particularly through the vitalization of our technology base, the stimulation of prototyping and the use of mature U.S. and Allied technology, and the reduction of intelligence asymmetry and "technological surprises" in the face of a determined and well supported Soviet competition. This effort includes the monitoring, assessment, and evaluation of the science and technology base in terms of potential for military utilization.

- Provide engineering support to obtain lower cost for weapon systems and equipment in production, operation, and support.

- Conduct advanced development and full-scale engineering development as appropriate.

- Achieve weapons equipment improvements which reduce the impact of projected manpower constraints.

- Provide scientific and engineering services and support to the operating forces.

- Develop, operate, and maintain major R&D facilities to meet specific needs unique to national defense requirements.

- Conduct mission analysis to identify system needs and deficiencies, both current and future, and determine preferred courses of action.

In accomplishing these functions, it should be stressed that a primary purpose of the laboratories is to develop and nurture new technologies to support their missions. The importance of this role for the in-house laboratories--the extension, development, and constant improvement of the technology base underlying all future development efforts--is fundamental. Unfortunately, this function is easily lost in the flood of product improvements, "quick-fixes" and concern over current operational problems--often the result of previous neglect to the technology base. It is imperative that the laboratories remain on the cutting edge of technologies critical to future military systems, both through their own research programs and through fostering and synergizing the results of such research, in the academic and industrial segments of the research community.

Further underscoring the need for competent and creative DOD in-house laboratories are reasons such as the following:

- The maintenance of national competence during peacetime, as well as times of conflict, in those areas of technology peculiar to military needs.

- The necessity for maintaining a continuity of effort, free from excessive commercial pressures, directed toward the conception and evolution of advanced military systems and equipment.

- The need for competent in-house skills to carry concepts through the planning, programming, and budgeting process for support of direct in-house work and for potential contract placement, monitoring, and assessment, and the ability to execute R&D as appropriate.

- The requirement to have available to the DOD a fast-reaction capability to solve critical, immediate problems that arise in connection with existing operational weapons systems and other items, and when unexpected combat situations are encountered (such as some of those experienced in Southeast Asia and the Middle East).

Figure 1 shows ten major goals and objectives for the DOD in-house laboratories. Secondary roles include such things as providing a training base for junior and senior military personnel, and for civilians who can transfer to headquarters and to nonlaboratory DOD elements involved in science and technology activities.

Figure 2 shows the major required in-house functions for DOD R&D and associated organizations involved in fulfilling their roles. Accordingly, the DOD has nurtured its laboratories for several decades to establish an environment conducive to the exchange of technical information and the exercise of judgment tailored to effective overall management. The bonds integrating the laboratories with a wide array of DOD research, development, and acquisition activities are complex and important.

FIGURE 1

DEPARTMENT OF DEFENSE
GOALS AND OBJECTIVES FOR RESEARCH AND DEVELOPMENT LABORATORIES

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. Maintain a continuity of effort, free from excessive commercialization pressure, directed toward the conception and evolution of advanced military material and support technologies.

4. Pursue technology initiatives through the planning, programming, and budgeting process; allocate work among private sector organizations and government elements.

5. Act as principal agents in maintaining the technological base of DOD.

6. Provide material acquisition and operating system support.

7. Have available a fast-reaction capability to solve critical, immediate technical problems that arise when unexpected operational situations are encountered.

8. Stimulate the use of technical demonstrations and prototypes to mature and exploit U.S. and allied technologies.

9. Carry out activities having high technological risk or requiring intensive resource investment not available from the private sector.

10. Interface with the worldwide scientific community; provide support to other government agencies.

SOURCE: Department of Defense

FIGURE 2

MAJOR DEPARTMENT OF DEFENSE RESEARCH AND DEVELOPMENT FUNCTIONS

1. BASIC RESEARCH - Increasing knowledge and understanding in fields directly related to long-term national security needs.

2. EXPLORATORY DEVELOPMENT - Developing and evaluating technical feasibility for solving broadly defined problems.

3. ADVANCED DEVELOPMENT - Systematic knowledge application toward production of useful materials, devices, systems, or methods.

4. ASSESSMENT OF SCIENCE AND TECHNOLOGY BASE - Continuous monitoring, assessment, and evaluation in terms of potential for military utilization.

5. MISSION ANALYSIS - Identification of systems needs and deficiencies, current and future, and determination of preferred courses of action.

6. CONCEPT EXPLORATION/SYSTEM VALIDATION - The feasibility study, development, and refinement of system concepts in response to military needs.

7. FULL-SCALE ENGINEERING DEVELOPMENT - Hardware engineering for Service use prior to approval for procurement.

8. ENGINEERING IN SUPPORT OF PRODUCTION - Periodic testing of production hardware, failure analysis, establishment of corrective actions, technical documentation control, and review of proposed production changes.

9. TEST AND EVALUATION - Determination of whether systems meet established performance objectives prior to release to production.

10. MAJOR RDTE FACILITIES - Facilities to meet specific needs unique to national defense requirements.

11. SERVICES AND SUPPORT TO OPERATING FORCES - Includes installation and testing, design deficiency correction, system improvement/retrofit, training, and logistic support.

SOURCE: Department of Defense

E. ISSUES

DOD laboratory management involves several issues which in the end merge into a single issue--how can the DOD increase the effectiveness of its personnel and funding resources for laboratories. This is, of course, much too large an issue to be taken in one bite. Ths single problem, insofar as the laboratories are concerned, may be viewed as consisting of the following primary issues:

- Achieving balance between available manpower and tasking within funding constraints.
- Obtaining adequate flexibility for management.
- Ensuring proper degree of intra- and inter-laboratory coordination.
- Providing appropriate performance incentives and work environment.
- Developing a program structure conducive to realization of goals.
- Maintaining a proper mix of in-house and contract R&D.
- Developing adequate mechanisms for performance assessment.
- Changing priorities
- Making long-term projections

These and other similar interests lie at the heart of the maintenance and development of the laboratory infrasturcture and the general health of the defense technology establishment. What is needed is full recognition that continuous concerted attention and assistance is essential.

F. CURRENT SITUATION

The DOD has been and is developing approaches that will further improve management of its laboratories. These actions are in various stages of advancement, some establishment, some evolving. Included in these actions are two dominant interrelated thrusts:

- The establishment in 1979 of the DOD Laboratory Management Task Force (LMTF). The LMTF is a standing working group chaired by the Office of the Secretary of Defense involving senior laboratory managers from the three military departments. This group has aggressively addressed a variety of laboratory-oriented issues and has obtained major improvements in policy and procedures. It continues to be a model of joint cooperation and action to focus on the welfare of the DOD laboratories.

- Renewed commitment to addressing the imposing challenges to U.S. technological superiority and the addressing of hard issues underlying the vitality of defense science and technology.

These thrusts and associated efforts directly affect the laboratory issues of image, operations, and long-term perspectives. They have resulted in management initiatives to:

- Provide laboratory managers with the responsibility, authority, and flexibility to manage laboratories and technical programs through use of broad guidelines and without overlapping controls.

- Ensure competency of personnel by:

  - Recognizing clearly that the most valuable resource of the laboratories is the capability, skill, and creativity of their personnel.

  - Providing for personnel stability, challenging work, and meaningful incentives.

  - Providing for equal opportunity for career development, training, promotion, recognition, and reward.

- Upgrade facilities and equipment by:

  - Removing limitations which constrain modernization of laboratories.

  - Promoting productivity, energy efficiency, and cost avoidance through policies which provide for modern facilities and equipment.

  - Basing replacement policies on practices that befit the business venture nature of research and development activities.

- Provide effective procedures for procurement and acquisition by:

  - Providing laboratories with the authority and capability to make procuremnts and acquisitions in a timely and efficient manner.

- Ensuring technical acceptability in contractor performance.

o Achieve continuing assessment and accountability by:

- Conducting periodic evaluations to assess the health of the laboratories, the quality and quantity of their contributions, and their performance against the public's legitimate expectations of efficient and effective use of personnel and financial resources—including the vigor of their partnership with industry and the academic community.

G. PERSONNEL - A CENTRAL CONCERN

Over the years there have been numerous high level review groups both internal and external to the DOD, which have examined the state of DOD in-house laboratories. These panels have found that the laboratories are necessary and perform a vital function reasonably well. They do this despite conditions which make such performance extremely difficult. Each panel has recommended actions to mitigate the negative environmental factors identified. There is a consistancy across these recommendations from panel to panel, and from year to year, suggesting that serious problems degrading the laboratories performance remain unchanged despite repeated identification. Representative major review panels since 1980 have included:

o DOD Laboratory Management Task Force - report of management constraints on the laboratories (1980)

o Defense Science Board Summer Study of the DOD Technology Base (1981)

- o Joint Logistic Commanders Study of Engineers (1981)

- o Defense Science Board University Responsiveness Study (1982)

- o Independent Review of DOD Laboratories (1982)

- o Army Science Board Summer Study of Army Military and Civilian Scientists and Engineers (1982)

- o DOD Laboratory Management Task Force Study of Scientists and Engineers in DOD Laboratories (1982)

- o National Academy of Sciences Report on the Professional Environment in Army Laboratories and its Effect on Scientific and Engineering Performance (1983)

- o White House Science Council Federal Laboratory Review Panel (Packard Committee) (1983)

- o Report to the President on implementing the recommendations of the White House Science Council Federal Laboratory Review Panel (1984)

Major recommendations for corrective actions may be summarized as:

- o Aggressively recruit scientists and engineers (S&Es).

- o Adjust S&E pay scale to meet services' needs and market competition.

- o Develop a systematic integrated pre-college through postdoctoral fellowship/career development program to attract, retain, nurture, and develop S&E personnel and skills identified as critical to service needs—include informal training, such as conference attendance.

- Modernize laboratory equipment and facilities—review on regular basis, priorities requirement and implement.

- Remove personnel and high grade ceilings--let mission and program dollars drive personnel levels, holding laboratory directors responsible.

- Increase support personnel to S&E ratio--which will enable S&Es to better perform their critical roles.

- Provide laboratory directors with maximum possible flexibility to manage resources and review results for their respective areas of responsibility.

- Establish a scientist and engineer personnel system which includes flexibility to rapidly employ both permanent and temporary senior specialists.

- Improve links with universities--develop cooperative arrangements, centers of excellence, and significantly increase basic research in the university sector.

One of the major recommendations made by the White House Science Council's Federal Laboratory Review Panel was to create a scientific/technical personnel system that would be independent of the current Civil Service system. Since October 1983 an interagency group under the Federal Coordinating Council for Science, Engineering, and Technology has been working on that recommendation. What is needed is a system which would:

- Permit agencies to include scientific and technical personnel in the new personnel management systems;

- Simplify job evaluation and remove covered positions from the position classification requirments of 5 U.S.C., chapter 51;

- Provide flexibility to develop salary structures which ensure a competitive position in the labor market and which reflect the hiring and pay policies needed to attract, retain, and motivate a highly qualified scientific and technical work force;

- Base pay increases on performance, not longevity;

- Allow limited waiver of pay cap for up to five percent of specially qualified scientific and technical personnel;

- Provide for performance and special awards and remove pay cap for lump-sum awards; and

- Permit the creation of a Senior Scientific and Technical Personnel Service.

Modern research facilities, equipment, and instrumentation are also required to attract, retain and motivate the best scientists and engineers. Each year, the in-house laboratories compete for the limited funds budgeted within each Service for military construction (MILCON) projects required for laboratory modernization and associated equipment. The competition is keen and many projects and equipments deserve support. During FY86, DOD will assess in-house research facility and instrumentation requirements. These needs will be reflected in future budget requests; an effort paralleling the multiyear upgrading of university laboratories may be called for. As an example, the DOD laboratories critically need improved access to supercomputer technology; options are being explored.

Another area of serious concern is contracting for technology support. The procedures currently existent are, at best, usually cumbersome and lengthly. As currently configured they have a negative impact on the efficiency and effectiveness of laboratory science and engineering personnel. This situation is particularly critical in the area of evolving science and technology.

H. DOD POSTURE AND RECOMMENDATIONS

The foregoing sections provided a highly condensed summary of representative DOD involvements to address the issue of the maintenance and development of technical skills in the DOD laboratories. This summary clearly demonstrates a heightened awareness on the part of top management, in the Office of the Secretary of Defense and in each of the military departments, of the need to focus on laboratories and their institutional needs. As a result of this intensified managerial attention, numerous improvements have been made and action to achieve others is in progress.

To assist DOD in addressing the effective mission performance of in-house laboratories, we need an alternative personnel management system to improve the quality of scientific and technical personnel. This system would improve our management flexibility and ability to attract, retain, and motivate a qualified scientific and technical workforce.

In summary the DOD must address barriers to good laboratory management, especially in the following areas:

- <u>Personnel</u> - We need a performance-based personnel management system for Scientists and Engineers. It should give supervisors a major role in the position description and classification of people.

- <u>Facilities</u> - We need an aggressive program for 15 years to modernize and update laboratories, facilities and instrumentation.

CHAPTER IV

DOD-INDUSTRY INTERACTIONS

A. INTRODUCTION

This chapter addresses the DOD research and development program performed by U.S. industry. This represents approximately 68 percent of the $31 billion FY 1985 research, development, test, and evaluation program (RDT&E) funded by DOD. Differences between R&D and systems acquisition contracting needs are discussed broadly. Specific DOD initiatives with respect to large corporations (Independent Research and Development-IR&D) and small corporations (Small Business Innovative Research-SBIR) are examined. Simplification of the contracting process for small R&D contracts is recommended; this would require legislative action.

B. IMPORTANCE OF INDUSTRY TO NATIONAL DEFENSE

A strong free enterprise economy and industrial base--here and abroad--are the essential underpinnings of our defense posture. Investment in our technology base and maintenance of our technological strength are critical to the long term security of the U.S. and our allies. Success in achieving the military posture we need is highly dependent on modern technology and its coordinated application.

DOD cannot effectively field this technology without an increasingly efficient industrial base.

C. CONTRACTING ISSUES

DOD contracting for R&D as well as systems acquisition is defined through public law, implemented through the Federal Acquisition Regulations, and further interpreted by Service regulations. Service interests are primarily in systems acquisitions involving large dollar amounts that are subject to considerable Congressional scrutiny. Examples of such systems include the B-1 aircraft, the TRIDENT submarine, and the M-1 tank. These systems acquisitions are characterized by large numbers of items generally integrated by a major contractor with many subcontractors. The contracts are typically competitive, multiyear procurements encompassing provisions for large numbers of items and many spares for subsystem replacement or maintenance.

The DOD Science and Technology program, by contrast, is quite different in content and approach. In the DOD laboratories, scientific and engineering personnel are searching for new innovative ideas and better ways to solve persistent problems either of which may lead to totally new capabilities. Laboratory contracts, on the average, are much smaller (in dollar value) than system contracts and are likely to be one-of-a-kind demonstrations rather than large numbers of similar items. This contrast suggests that there may be a need for special contracting provisions for the laboratory community.

A review of Air Force data for basic research shows that the average contract or grant is approximately $95,000 per year. A similar review of exploratory development gave an average contract size of approximately $195,000 per year. Although the Army and Navy did not collect data in a similar manner, it can reasonably be assumed that most contracts in the Science and Technology (S&T) program are less than $300,000 per year. Using $300,000 as a point of reference gives about 10,000 procurement actions for the FY 1985 DOD program in research and exploratory development ($3,380 million). This simple calculation gives an idea of the contracting workload generated at the laboratories in a typical year. It also is indicative of the potential benefits of the simplification of contracting procedures.

In recent years, there have been significant changes in procurement law relating to competition and innovation. They have generally lengthened the contracting process. A quick review of these changes yields the following added requirements to the contracting process:

a. Small business subcontracting plans - required in contracts/modifications expected to exceed $500,000 with the potential for subcontracting (small business concerns are exempt).

b. 30 day delay for RFP issuance for proposed acquisitions in excess of $10,000.

c. Requirement to allow at least 30 days for proposal preparation.

d. Approval of the Head of the Contracting Activity on all proposed sole source acquisitions over $500,000 (to be increased to $1,000,000 in April 1985).

e. Lowering of the threshold for certified cost and pricing data from $500,000 to $100,000.

These changes have generally lengthened the contracting process for the technology base.

To fulfill their missions, DOD laboratories must keep abreast of new developments in science and technology. This is an ongoing process, made more challenging as the pace of R&D innovation, both foreign and domestic, accelerates. Activities pursuant to this objective range from the review of industry IR&D programs to soliciting new ideas from universities and industry including small business concerns. The IR&D program and the Small Business Innovative Research program are discussed in Sections D and E of this chapter. The special instrumentation program for universities has already been discussed in Chapter II.

The discussion thus far has developed a perspective for laboratory technology, but leads to some philosophical questions which should be considered, i.e.,

a. Should there be special procedures for small contracts?

b. Should there be special procedures for DOD (and, perhaps, all Federal) laboratories for the purpose of stimulating technology transition and special cooperative efforts?

D. INDEPENDENT RESEARCH AND DEVELOPMENT (IR&D)

IR&D, as defined by DOD, is a contractor-funded R&D program. The R&D efforts are chosen and conducted by the contractor to maintain and improve his technical competence and competitive position in the marketplace. Thus if a company must continually come out with new and updated products to remain competitive, it is advantageous to conduct an IR&D program to develop these new or improved products. Manufacturers of automobiles, minicomputers, word processors, steel, aluminum, plastics, air conditioners, and refrigerators are typical examples of commercial sector companies that would be likely to conduct IR&D programs. In any given year, companies recover IR&D program costs through sales of their products. These products could be end items, such as airplanes, boats, and automobiles, or the results of research performed on R&D contracts. Likewise, companies that develop weapon systems or subsystems must conduct IR&D programs to remain competitive in the DOD market place.

DOD has the following objectives for the IR&D program:

a. Encourage innovative R&D efforts for DOD systems and equipment which complement and broaden the spectrum of DOD concepts.

b. Develop technical competence in two or more contractors to encourage competitive responses to DOD procurement efforts.

c. Contribute to the economic stability of the private sector by allowing companies sufficient technical latitude to develop a wide variety of products for a broad base of DOD customers.

DOD currently has two special thrusts for the IR&D program: increasing industry-university interactions and emphasis on weapon system support and readiness issues. These thrusts are described below.

a. Industry-University Interactions - The goal is to encourage increased interactions between DOD contractors and universities, both to strengthen the technical manpower base from which industry draws, and to increase the rate of technology transition from the academic community to industry. Desired interactions are those that strengthen research capabilities of the universities in science and engineering, contribute to development of high quality science and engineering graduates, and promote transition of research results into new applications.

b. Weapon System Support and Readiness - Improvements in support and readiness are major DOD objectives in the weapon system and logistic support technology areas. Technical innovation is essential in order to improve the readiness of our systems. Increased emphasis is required on technology areas which increase mission reliability, reduce dependence on support equipment, spares, and repair facilities, and reduce the need for highly-skilled personnel. Since these objectives are being integrated into DOD programs, it also is important that these objectives be reflected in defense contractor IR&D programs.

DOD manages the IR&D program in accordance with the requirements of Public Law 91-441, Section 203(a). This law authorizes DOD to pay IR&D and bid and proposal (B&P) costs only if the work for which payment is being made is relevant to the functions or operations of DOD and if specific conditions (discussed below) are met for companies that recover more than $2.0 million in IR&D and B&P costs per year from the DOD. Public Law 96-342, Section 208, raised this threshold to $4.0 million and delegated authority to the DOD to increase this threshold every third year consistent with economic criteria. The next paragraph describes DOD activities which meet the specific conditions of Public Law 91-441, Section 203(a), as amended by Public Law 96-342, Section 208.

a. DOD currently negotiates advance agreements establishing a dollar ceiling on IR&D and B&P costs with all companies which, during their preceding fiscal year, received more than $4.4 million of IR&D and B&P payments from DOD. These ceilings are either negotiated directly with each such company or with those product divisions within a company which contract directly with DOD and which received more than $550,000 of IR&D and B&P payments from DOD. The IR&D ceiling is based on a contractor-submitted technical plan which DOD evaluates prior to or during the fiscal year of the advance agreement. DOD's allocable share of a company's IR&D and B&P costs can be no larger than the dollar value of IR&D and B&P efforts which have a potential relationship to a military operation or function.

b. For companies which during the preceding fiscal year received less than $4.4 million of of IR&D and B&P payments from the DOD, the IR&D and B&P ceilings are set by formula (Federal Acquisition Regulation 31-205.18). While the company does not have to submit a detailed technical plan to DOD for evaluation, it must submit a summary of the individual IR&D projects to the Administrative Contracting Officer responsible for determining the overhead rate for the company. Again, DOD's allocable share of a company's IR&D and B&P costs can be no larger than the dollar value of IR&D and B&P efforts which have a potential relationship to a military operation or function.

The growth of IR&D expenditures by contractors is shown below. Also, the percentage of these IR&D costs allocable to DOD has increased, due primarily to the growth in the DOD budget and the concurrent downturn in commercial sector sales.

IR&D COSTS
(Millions of Dollars)

Fiscal Year	1980	1981	1982	1983
Contractor-Incurred Costs	2373	2746	3654	3930
DOD Share	745	936	1193	1441

In order to focus IR&D Programs to meet DOD requirements, DOD interacts in several ways with contractors on technology base requirements:

a. Requirements information is transmitted to contractors through the technical comments made by individual evaluators during the annual review of contractor-submitted IR&D technical plans. Requirements information also is transmitted during formal and informal IR&D on-site reviews of the individual contractor programs.

b. Contractors discuss future requirements with the technology area focal points identified in the requirements documents issued by each Service. These documents are available to both current and potential contractors through each Service's Information for Industry Offices.

c. Most Service laboratories brief industry representatives annually on future requirements.

The following actions are recommended to improve DOD-contractor interactions on technology base requirements:

a. All DOD and Service R&D organizations should update their requirements documents and lists of technology area focal points on an annual basis.

b. All DOD and Service R&D organizations should brief industry annually on future technology requirements.

c. All Service R&D organizations should continue to emphasize technical interaction with IR&D programs, including participation on both IR&D technical plan evaluations and on-site reviews. Industry IR&D planning will be influenced as companies gain further insight into DOD requirements. Likewise DOD planning will be influenced by the improved communications and understanding of technology emerging from industry.

E. SMALL BUSINESS INNOVATIVE DEVELOPMENT (SBIR) PROGRAM

On July 22, 1982, the President signed the "Small Business Innovation Development Act of 1982" (P.L. 97-219). This law was designed to give small high technology firms a greater share of Federal research and development contract awards. It became effective on October 1, 1982.

The Act mandated that all Federal agencies establish an SBIR program if their FY 1982 extramural budgets for research and development exceed a threshold figure of $100 million. (There are twelve government agencies meeting this requirement.) Beginning in FY 1983, DOD had to make available the following percentages of its extramural R&D budget for this program:

Fiscal Year	1983	1984	1985	1986	1987	1988
Percentage	0.1	0.3	0.5	1.0	1.25	1.26
Estimated Amount (Millions of dollars)	16.7	44.0	79.0	160.0	204.0	262.0
Actual Award (Millions of dollars)	20.6	44.6	--	--	--	--

Objectives of the DOD SBIR Program include stimulating technological innovation in the private sector, strengthening the role of small business in meeting DOD research and development needs, fostering and encouraging participation by minority and disadvantaged persons in technological innovation, and increasing the commercial application of DOD-supported research or research and development results.

The SBIR Program consists of three distinct phases. Under Phase I, DOD components make awards to small businesses, typically of one-half to one man-year effort over a period generally not to exceed six months, subject to negotiation. Phase I is to determine the scientific or technical merit and feasibility of ideas or concepts submitted in response to SBIR topics. The topics are published annually in a competitive solicitation document to which small businesses respond with proposals.

All DOD topics address specific R&D needs to improve our defense posture. Awards concentrate on that research or research and development that significantly contributes to proving the scientific or technical feasibility of the proposed effort, the successful completion of which is a prerequisite for further DOD support in Phase II.

Phase II awards are not based on a solicitation but are made to firms on the basis of results from the Phase I effort and on the scientific and technical merit of the Phase II proposal. Special consideration is given to those proposals which identify a follow-on Phase III funding commitment from non-Federal sources.

Phase II awards typically cover 2 to 5 man-years of effort over a period generally not to exceed 24 months, subject to negotiation. The number of Phase II awards depends on the success rate of Phase I contracts and on the availability of funds. Phase II is the principal research or research and development effort, and requires a more comprehensive proposal outlining the effort in detail.

Phase III is expected to involve private-sector investment and support for any necessary development that will bring an innovation to the marketplace. Under Phase III, DOD may award non-SBIR-funded follow-on contracts for products or processes meeting the mission needs of DOD.

The legislation for this act was modeled after the Defense Small Business Advanced Technology (DESAT) Program instituted by DOD in FY 1982. In Phase I of DESAT, 100 contract awards of approximately $50,000 each were made from 1103 proposals received. From the 100 Phase

I awards, 33 Phase II awards worth $4.7 million were made. The DESAT awards are counted against the mandate of the SBIR Act for the fiscal year in which the awards are made. The DESAT program will be phased out with the completion of the current Phase II contracts.

FY 1983 SBIR Program

For the FY 1983 SBIR Phase I contract program, the three Services and the Defense agencies selected more than 300 research and development topics from a description of needs which were included in the DOD SBIR solicitation brochure. This solicitation had a closing date of May 31, 1983. The following is a breakout of the proposals received and those for which Phase I contracts were awarded:

	Number of Topics	Proposals Received	Phase I Awards
Army	182	1121	96
Navy	131	944	67
AF	75	496	100
DARPA	8	128	12
DNA	10	88	8
Totals	406	2777	283

FY 1984 SBIR Program

The solicitation brochure for the FY 1984 DOD SBIR Phase I Contract Program was mailed out on October 17, 1983 (approximately 42,000 copies were distributed) with a closing date of January 12, 1984.

Resulting proposals were evaluated by the scientists and engineers in the Services and Defense agencies who generated the topic descriptions. The announcements of proposals selected for contract negotiations were made by the Secretary of Defense on August 1, 1984. A breakout follows:

	Number of Topics	No. of Proposals Received	No. Selected for Phase I Negotiations
Army	111	761	78
Navy	147	847	99
Air Force	283	1212	164
DARPA	17	107	15
DNA	8	80	12
Totals	566	3007	368

Of the 283 FY 1983 Phase I contract awards, the following Phase II contract awards are anticipated:

Army - 30 to 35

Navy - 37

Air Force - 50

DARPA and DNA - 8

Funding of the two year Phase II contracts will be by yearly increments.

FY 1985 Program

The SBIR solicitation for Phase I proposals for FY 1985 began with the selection of the research and development topics by the Services and Defense agencies. This process was completed in August 1984. The topics were consolidated into a single DOD solicitation brochure and distributed on 1 October 1984. The Army has 111 topics, Navy 138, Air Force 218, DARPA 17, and DNA 7. Potential offerors had until 31 January 1985 to submit proposals. For FY 1985, the Strategic Defense Initiative Organization will have 18 topic descriptions in a supplemental DOD solicitation released on 1 January 1985, with a closing date of 31 March 1985.

The Small Business Administration (SBA) is charged by P.L. 97-219 with maintaining a source file of all small firms wishing to be notified of the availability of SBIR solicitations from all twelve agencies of the government. DOD makes an automatic mailing of its SBIR solicitations to all of the firms on SBA's mailing lists. The FY 1985 solicitation has been mailed to 21,959 small R&D high-tech firms.

F. RECOMMENDATIONS AND FUTURE PLANS

Based on the discussion in Section A, AF laboratories were asked for policy changes that might substantially reduce the contracting workload on contracts less than $300,000 per year. The responses were varied, but there was general agreement that several actions might be taken to reduce the contracting workload. Some actions would require only Service or DOD regulation changes.

Examples of procedural changes cited which would simplify laboratory contracting for small contracts include:

(1) Eliminating cost schedule reports.

(2) Eliminating the Small Business subcontract requirement.

(3) Relaxing of time accounting requirements.

Three recommendations for major changes (requiring FAR or law changes) were received as follows:

1) Set up an SBIR-like, set aside program for universities to which they can respond with simplified proposals. A portion of the technology base would be reserved for this program. This approach would resolve only a portion of the problem, as the university community represents only a part of the science and technology programs. Also the

university community generally competes well in the research program but does not go beyond applied research into development.

2) Revise PL 98-72 and the Competition in Contracting Act, to remove synopsis requirements for small contracts and consider other restrictions which may be eliminated to encourage more participation in laboratory contract programs without increasing paper work.

3) Arrange for a special contract/procurement instrument (in some ways similar to a grant for basic research) for the laboratory community which would allow simplified proposals, contracting procedures, and administration for procurements with obligations of less than $300,000 per year. This would require legislation to allow simplified procedures and a relaxation of data requirements for small contracts. A simple procedure is envisioned that could be applicable to small business, the university community, and those researchers in major industrial laboratories working on new technologies. The proposed instrument might also take the form of a cooperative agreement whereby DOD and the contractor/grantee would share costs, one buying equipment and the other providing workspace and salaries. It would appear that considerable savings in

time and effort could be made by allowing laboratory extramural programs more flexibility in 6.1 and 6.2 procurements with obligations of less than $300,000 per year. Furthermore, it is likely that both government S&E personnel and the proposer community would welcome a dialogue on the subject.

4) Authorize the use of small purchase procedures and forms for small R&D contracts or permit the use of purchase orders.

5) Give consideration to the use of Basic Ordering Agreements with task orders as an acceptable type of contract for certain R&D and R&D service requirements.

In summary, this chapter started with a discussion of laboratory programs in science and technology, and ways in which they differ from systems acquisition programs. Short sections on industry participation in IR&D and SBIR were included to give examples of the breadth of current programs which support the national technology base. The conclusions encompass a possible new approach to simplifying the technical interaction between government laboratories, industry, and universities. As a result of this study, DOD will propose draft legislation which would simplify contracting for small R&D contracts.

CHAPTER V

TECHNOLOGY BASE ACTIVITIES OF OUR ALLIES

A. OBJECTIVES

The United States and its allies are relying on superior technology to meet the threat posed by their adversaries. In sheer quantities of military resources, our adversaries have us outnumbered. We must, therefore, balance this numerical threat in part by relying upon qualitatively superior weapons systems to maintain our collective strength. By equipping our forces with weapons systems that are technologically superior to those of our potential adversaries, we use fewer people and increase the leverage of our defense dollars. To counter the threat in any other manner would require substantial increases in the military budgets of the U.S. and its allies.

So far, we have managed to stay ahead of the Soviets in most deployed technologies, but in some areas our lead is fragile and, in others, we are clearly behind. Several factors contribute to the loss of, or reduction in, our technological lead. One is the length of time required for weapons systems development. The period from beginning of development to actual deployment can be ten to twenty years, and a deployed life of twenty additional years is not unusual. The fruits of this long-term investment are seriously jeopardized if our potential adversaries obtain a system's technology early in its development or test cycle. In recent years, DOD has proposed substantial increases in its RDT&E budget for the purpose of deploying technology in weapons systems more quickly than we have in the past. The Congress has been very supportive of DOD's efforts in this regard.

The pluralistic makeup of our allies represents a second area of vulnerability. Joint allied use of advanced technology in weapons systems is subject to multilateral negotiations and mutual agreement among partners. As a result, progress in modernizing our forces is sometimes agonizingly slow, and this pace affords the Soviets time to narrow our technological lead.

The changing relationship between civilian and military technologies also makes our lead vulnerable. Thirty years ago, military technology was far ahead of that in the private sector; sophisticated military electronics had no civilian counterpart. Today the situation is very different. We increasingly find that military systems incorporate technology which already is in the marketplace. The micro-electronics revolution, for example, placed advanced computers in the hands of the public long before the military equivalents became part of weapons systems. This situation is of great benefit to the public, but makes it much more difficult to protect our technological lead in important technologies which are available commercially.

Finally, and perhaps most importantly, the massive Soviet effort to acquire Western military technology by both overt and covert means threatens our technological lead.

To maintain our technological lead, we must carefully steer a course between two extremes. On the one hand, we must not restrict technology exchange to such an extent that we actually slow the pace of allied technological development. On the other hand, we cannot be cavalier in the face of Soviet success in acquiring important technology. Like many difficult real-world problems, control of unfavorable technology transfer is within the realm of the possible; it requires a pragmatic approach that balances the competing policy considerations and also achieves a favorable benefit-cost ratio.

Our technological lead can be increased or maintained in two ways—by moving the West further ahead and by holding the Soviets back. Recognizing this, the United States has adopted an approach of promoting technology exchange and development with our allies, while at the same time restricting technology transfer to potential adversaries. These activities complement each other; neither can succeed alone.

With regard to export control, the United States has undertaken initiatives designed to restrict the flow of militarily critical technology to our potential adversaries. These initiatives constitute a realistic course of action. They recognize that it is impossible to prevent all undesirable technology transfer. Some transfer occurs and will continue to occur illegally. An open society, which is absolutely essential to our continued scientific and technological progress, creates some targets of opportunity for the Soviets that we can never fully protect.

The objective of export controls, then, is delay, not prevention. High technology is a perishable item and, during its useful life, we want to make the know-how difficult for the Soviets to obtain. If they do succeed, we want to make the effort as costly as possible. Let the Soviets expend their own resources to acquire high technology rather than get it from the United States and its allies at a fraction of what it cost us to research it, develop it, engineer it, manufacture it, and control its quality. We will be better able to maintain our advantage if the Soviet economy has to bear the full economic costs of technological innovations.

It is also important to recognize that the United States, with few exceptions, does not have a monopoly on technology. Therefore, if controls are to be effective, they must be multinational. Otherwise, American industry would find itself, in effect, excluded from marketplaces that are open to its foreign competitors.

Finally, our export control efforts acknowledge that the United States, as a practical matter, cannot police all activity of this kind. Consequently, the government's limited resources are concentrated on those areas offering the highest potential payoff.

B. CURRENT MECHANISMS FOR EXCHANGE, COOPERATION, AND COLLABORATION

DOD is working closely with U.S. allies to identify technological opportunities which make the best use of our combined resources and achieve the objective of maintaining superior technology for future weapons systems. In addition to informal approaches, there are several formal mechanisms which promote the objective. Among the latter are The Technical Cooperation Program, NATO's Defense Research Group, the Services' basic research offices in London and Tokyo, and, more recently, the technology assessment teams established to explore the transfer of military technology from Japan to the United States.

The Technical Cooperation Program had its origins in a Declaration of Common Purpose made in 1957 by the President of the United States and the Prime Minister of Great Britain. The statement recognized that the concept of national self sufficiency was out of date, that the countries of the free world are interdependent, and that progress and safety could only be found in genuine partnership by combining resources and sharing tasks in many fields. Since then, Canada, Australia, and New Zealand have joined the program. A number of subgroups were established in appropriate fields of defense research and development. Briefly, the purpose of the subgroups is to formulate proposals designed to obtain maximum cooperation and optimum employment of resources for research and development, and to ensure as complete an interchange of information as possible among the five countries in designated areas of the defense research and development technology base. Among the designated areas are chemical defense, undersea warfare, aeronautics technology, infrared and optical warfare, communications technology, behavioral sciences, and conventional weapons technology.

NATO has established the Defense Research Group. The Group consists of senior national representatives capable of speaking with authority on the application of science and technology to military problems and resulting national research programs. The Group has several objectives: to exchange information on new research and technology which might lead to future equipment; to review the possible military consequences of advances in the fields of science and technology; to identify suitable areas or individual proposals for bilateral or multilateral cooperation in defense research; to implement this research; and to avoid duplication of effort. Technical panels and research study groups have been established in physics and electronics, optics and infrared, defense applications of operations research, defense applications of biomedical research, electronic warfare concepts and technology, long-range research related to air defense, and long-term scientific studies (not technology specific). In addition, a special study group has been established in concealment, camouflage, and deception.

Recently, the NATO efforts have concentrated on emerging technologies in four mission areas: (1) defense against first echelon attack; (2) attack of follow-on forces; (3) counter-air; and (4) C^3I and counter-C^3I. The goal is to make visible and expeditious progress in cooperative efforts to field effective systems that would otherwise not be widely deployed--in other words, to concentrate on the utilization of more proven technologies in deployed systems.

More recently and of more interest to this report, there has been increasing attention to technology emerging from basic and applied research efforts. The increasing interest in being able to identify, at an early stage, the technologies which may be important to future defense systems is fueled as much by economic considerations as by security. Some of the questions which are being addressed are how to identify high-leverage technologies, whether an identification procedure could be used for an investment strategy, and what degree of protection or control should be provided.

The Services maintain research offices in the U.K. and Japan to meet their needs in matters relating to science and technology overseas. The primary responsibility of those offices is to keep informed on scientific and technological developments in Europe, the Middle East, and the Far East. The offices also establish contacts between American and foreign scientists in important technical areas and provide liaison between the U.S. and foreign scientific communities.

During the past two years, DOD has worked with the Japanese to implement the Nakasone Cabinet's January 1983 policy statement allowing the transfer of certain military-related technology to the U.S. DOD hopes to establish a long term program of cooperative efforts and transfer of technology. Our initial efforts have been toward assessing the status of Japanese technology in the area of fiber optics, electro-optics, infrared and millimeter wave components, and sensors. This was accomplished by a team of experts who visited Japan in 1984. The teams' assessment, conclusions, and recommendations are being evaluated in DOD.

C. SUMMARY

In Europe, both the need and the opportunity exist to increase cooperation with our allies. European economic conditions are not as favorable as those in the United States and, as a result, many countries are cutting back on research. European researchers are some of the best trained in the world, usually have excellent equipment, and, in certain areas have unique data gathering capabilities.

The situation with regard to Japan is somewhat different. The Japanese government, business managers, bankers, and researchers select their technological areas based on long term national industrial and economic needs. Although excellent basic research is conducted, the emphasis is definitely on the application of technology. This does not mean, however, that there are no opportunities for increased collaboration.

As described in this report, there are many joint programs, joint developments, joint experiments, and data and information sharing activities with our allies. Where appropriate, the cost of this effort is shared. Since the United States and its allies are relying on superior technology and the leverage it provides, it is essential that we reexamine the resources that the United States is applying to the technology base portion of DOD's RDT&E budget. Otherwise, future weapons systems will not have the leverage of superior technology and the United States would have to increase its defense expenditures in an effort to match adversaries tank for tank, plane for plane, man for man.

CHAPTER VI

CONCLUSIONS

DOD recognizes the importance of the nation's scientific establishment to our future security. This establishment, a combination of our universities, industry, and in-house laboratories, requires continued attention to ensure that it is sustained at a sufficient level, and is of sufficient quality, to maintain our technological lead over potential adversaries.

This report, prepared at the request of the Senate Committee on Armed Services, has addressed the DOD S&T program and has identified areas which need and are receiving special attention. see p 2+3

- Additional funding is needed to pursue defense science and technology programs required to sustain a U.S. technological lead. Two specific actions have been taken. Approximately 9 percent real growth has been requested in the FY 1986 budget. In addition, the Secretary of Defense has issued guidance for real growth in both the Basic Research and Exploratory Development Programs starting in FY87.

- A DOD-University Research Initiative to help revitalize university science infrastructure as a step toward maintaining the S&T base required for national security has been included in the FY86 budget. Particular attention will be given to potentially high payoff projects in emerging technologies, research instrumentation, graduate fellowships, and research assistantships.

In addition:

- Improvements in the quality of the scientists and engineers at in-house laboratories as well as universities are being sought. A new personnel management system for scientific and technical personnel in the Federal government is needed to improve management flexibility and the ability to attract, retain, and motivate a high quality scientific and technical workforce.

- Research instrumentation is needed to provide scientists and engineers with the tools required to perform quality work. FY 1986 will be the fourth year of a five year, $150 million program to upgrade instrumentation of universities performing defense-related research. In addition, DOD is assessing university facility needs to perform defense-related research. The report on this assessment is in preparation and will be provided to the Congress when completed. During 1986, DOD will assess in-house laboratory research instrumentation and facility requirements. These needs will be reflected in future budget requests.

- Efficient interactions in the S&T Program among the in-house laboratories, universities, and industry are needed. DOD currently is reviewing potential changes to internal procedures in order better to accommodate the Federal Acquisition Regulations, PL 98-72, and the Competition in Contracting Act. If necessary, draft legislation will be proposed to facilitate these activities.

- S&T cooperation and collaboration with our allies, which engenders a larger common technology base and enhances mutual understanding of defense technologies is strong and should be strengthened if possible. Bilateral and multilateral agreements for jointly developing and sharing technology are being improved with particular emphasis on agreements with NATO, The Technical Cooperative Program countries, and Japan.