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ABSTRACT

This report describes Department of Defense (DOD) education programs in certain science, engineering and technical fields. It does not cover the extensive in-service technical training and education programs DOD maintains to prepare military personnel for specific occupational specialties, and managerial and leadership responsibilities. Section I, "Historical Overview of Congressional Concerns and Federal Funding for Science and Engineering Education," discusses the pre- and post-Sputnik eras and federal funding through the National Science Foundation and the Department of Education. Section II, "Science and Engineering Concerns," discusses the supply and demand for scientists and engineers, demographics and the science and engineering talent pool, and options to improve science and engineering education programs. Section III, "Science and Engineering Personnel in the Department of Defense," discusses whether or not the United State's defense buildup might cause a drain on the number of scientists and engineers from the civilian sector and whether this drain has an adverse effect on the United States' competitiveness. Section IV, "Department of Defense Science Education Initiatives," describes precollege, undergraduate, and graduate programs sponsored by the DOD. The last section discusses options to increase the DOD's role in science and engineering education. (KR)

CRS Report for Congress

Science and Engineering Education: The Role of the Department of Defense

Christine M. Matthews
Analyst in Science and Technology
Science Policy Research Division

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CRS

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SCIENCE AND ENGINEERING EDUCATION: THE ROLE OF THE DEPARTMENT OF DEFENSE

SUMMARY

The Bureau of the Census reports that the population base from which future scientists and technicians are taken will have a significantly different racial mixture from that of the past. By the year 2000, approximately 85 percent of the new entrants to the U.S. labor force are expected to be minorities, women, handicapped and immigrants, groups, which for the most part, have been historically underrepresented in science and technical related fields. These demographic phenomena are projected to have a significant impact on the economy, social structure, and labor force and may affect the Nation's and the Department of Defense's (DOD) ability to meet future needs in science and engineering fields.

Presently, there are a number of education programs in the DOD which are designed to attract, train, and advance a sufficient supply of fully qualified individuals in science, engineering and technical fields. Some of these programs are directed primarily at minorities and women who are proportionally underrepresented in DOD's scientific and technical workforce. Precollege programs in the DOD have provided support for more than 4,000 high school students to participate in research projects at colleges and universities. The DOD provides undergraduate cooperative programs for science and engineering laboratories. At the graduate level, the DOD provides approximately 200 graduate fellowships and 7,000 graduate assistantships in institutions working on defense contracts. In addition, it is estimated that approximately 75 percent of the 21,000 Reserve Officers Training Corps scholarships are targeted for science and engineering majors.

The range of programs designed to increase the availability of scientific and technical skills in the DOD workforce is extensive. However, projected demographic changes and constrained resource conditions are expected to be exacerbated in the coming years. Expansion of current programs or creation of other programs have been proposed in order to guarantee the availability of skill levels demanded by the emerging workforce. Greater coordination within the DOD and between other Federal agencies may also be necessary to ensure both cost effectiveness and program efficiency of any intervention efforts. In addition, evaluation of all existing and new programs may be needed to determine the quality of programs and to ensure that objectives are being achieved. The DOD and other Federal agencies are in the position to contribute to improving science education, be it by stimulating the changes that are needed or in serving in a more complementary role. If Congress decides on a further DOD role in improving science education, DOD's effectiveness will depend on numerous factors including available resources.

This report describes DOD education programs in certain science, engineering and technical fields; it does not cover the extensive in-service technical training and education programs DOD maintains to prepare military personnel for specific occupational specialties, and managerial and leadership responsibilities.

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NOTE

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SCIENCE AND ENGINEERING EDUCATION: THE ROLE OF THE DEPARTMENT OF DEFENSE

INTRODUCTION

A capable scientific and technological workforce is an important part of U.S. efforts to improve economic competitiveness of key industries. Concern has been expressed about the status of the U.S. science and mathematics base--specifically, the human talent, knowledge, and infrastructure that generates innovations and undergirds technological advances to achieve national objectives. There seems to be a general consensus that the requirement for science, engineering and technical occupations will increase in the next decade, at a more rapid pace than has been experienced in the past. Specifically, the Department of Defense (DOD) can expect an increased demand for science and engineering personnel, as a result of turnover, technological advances, and skills shifts, and that the increased demand within the Department and the general labor market will outstrip the projected supply in these disciplines by the year 2000. The projected long-term shortage of qualified individuals in science and engineering and technical fields is expected to shape the U.S. labor force and impact directly on the DOD's ability to meet its future needs.

I. HISTORICAL OVERVIEW OF CONGRESSIONAL CONCERNS AND FEDERAL FUNDING FOR SCIENCE AND ENGINEERING EDUCATION

A. PRE-SPUTNIK (1953-1957)

Both the Congress and the National Science Foundation (NSF) have served important roles in the growth and strengthening of U.S. science and engineering education since the establishment of the NSF in 1950. The concern for an adequate supply of scientific and engineering personnel for the United States is not new; NSF, for example, noted in 1953:

The National Science Foundation, in its second annual report to President Truman, warned today of a critical shortage of scientists in the United States that is expected to grow worse in the next few years.

> . . . [C]ontrasted to that in the Soviet Union, where governmental programs call for schooling of technical and scientific experts . . there will be only 15,000 engineering graduates [in the United States] in 1955, [compared] with 50,000 in the Soviet Union, where there had been only 9,000 in 1943.
>
> In the engineering field, . . . the shortage tends to feed on itself. College seniors are besieged with personal representatives, so that many students have a choice of jobs upon graduation. Under these circumstances, the Foundation concluded, it is too much to expect the requisite number of promising students to turn down offers of $3,000 to $6,000 a year in favor of spending three or four more years in postgraduate work.[1]

At that time, many congressional members had also concluded that the Soviet Union was outdistancing the United States in its training of scientific and technical personnel. Senator Alexander Wiley, speaking before a Senate Committee in 1954 stated that:

> . . . [T]he Soviet Union was far outdistancing us in expanding the reservoir of skilled engineers, scientists, and other technicians. Under these circumstances, for us to fail to provide adequate incentive to talented young scientists is to be committing, in my judgment, a tragic blunder.[2]

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[1] Lack of Scientists is Called Critical: 2nd Report of U.S. Foundation Says Russia is Outdistancing Us in Engineering Graduates. New York Times, Jan. 17, 1953. p. L17.

[2] Wiley, Alexander. More Adequate Use of Scientific Manpower. Remarks in the Senate. Congressional Record, Daily Edition, Aug. 6, 1954. p. 13505.

Primarily because of this concern for the supply of sciences and engineers and coupled with interest in increased funding for science education, the NSF was mandated to "promote the progress of science", and to develop and implement programs to attract more students to science. In the mid 1950s, the NSF convened scientists and science educators to identify classroom problems. The consensus during that period was that the students at the precollege level were disinterested in science, the curricula was obsolete, and that classroom teachers were unprepared for teaching science. The most marked finding was that the supply of new scientists and technicians was decreasing following a surge during World War II.

Even though the supply of new scientists and technicians had decreased significantly following a surge during World War II, opposing views were held as to the actual existence of a shortage. As early as 1954, the director of NSF, Alan T. Waterman, argued that the shortages of scientific and technical workers would correct themselves. He stated that: " . . . shortages of scientific and technical workers were confined to a few fields, and likely to improve. Any dramatic emphasis on the problem might lead to oversupplies."[3]

B. POST-SPUTNIK ERA (1958-1970)

The Soviet Union's launching of the first satellite into orbit on October 4, 1957, set off a massive national effort for the United States to catch up in space and galvanized the educational system into a sudden effort to significantly improve math and science education curricula. Pressure from the public and action by Congress, in addition to a plethora of reports and recommendations emphasizing the shortcomings of U.S. scientific education, increased both Federal interest and involvement in education.

Enactment of the National Defense Education Act of 1958 (NDEA) was the first major Federal effort to act on the Nation's educational system in response to the Soviet launch of the Sputnik satellite. The legislation had a scientific focus, providing $295 million for direct student loans, with "preference" for those planning a teaching career or intending to pursue the study of science, math, engineering, or a modern language.[4] It was an emergency program specifically directed at producing scientific personnel, and quickly broadened prior to its initial four-year authorization.

> The 1958 National Defense Education Act (NDEA) was important not so much because of the specific provisions . . but because of the psychological breakthroughs it embodied. It asserted, more forcefully than at any other time in nearly a century, a national interest in the

[3] Lomask, Milton. A Minor Miracle: An Informal History of the National Science Foundation. Washington, U.S. Govt. Print. Off., 1976. NSF 76-18. p. 121.

[4] Ibid., p. 18.

quality of education that the states, communities, and private institutions provide.[5]

In addition to the NDEA, enactment of the Higher Education Acts of 1963 and 1965 expanded the Federal role in education. However, the Federal role clearly remained supplementary to the States.

Following Sputnik, the NSF increased the promotion of science and science education, and increased support for improving precollege science curricula and teacher training. Funding became more plentiful, and the focus of science education ran from content to process and method. Support for science and engineering education in the NSF increased from 16.8 percent of the total NSF budget in fiscal year 1955 to 38.4 percent in fiscal year 1958 and 46.1 percent of the total budget in fiscal year 1959.[6] In addition to the NSF, many school districts initiated their own science education programs while other school systems engaged in collaborative efforts with universities and industries. Other Federal agencies and the private sector also provided support for the improvement of precollege science education in an effort to increase U.S. production of scientific and engineering professionals.

During this post-Sputnik period, research scientists and science educators defined, studied, developed and instituted science programs to expand the production of scientists and engineers. Elementary school curricula were introduced to allow children to use scientific inquiry techniques in order to apply the process of science. During the 1960s, as a result of education specialists and curriculum innovations, and research on how children learn science concepts, efforts were made to emphasize hands-on (laboratory) experiences at all levels of science education.

Prior to the launch of Sputnik, the NSF had initiated a project to develop science and mathematics curriculum reform at the precollege level (the Course Content Improvement Program) that culminated in the 1960s with a curriculum offering a full spectrum of science courses--basic science, chemistry, physics, biology and mathematics. The NSF also established inservice and summer institutes for teacher training. By 1969, more than 40 percent of the Nation's high school teachers had participated in the institutes.[7] These programs proved effective for improving the training of young engineers and scientists, many of whom entered the space and energy programs at the national level.

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[5] The Federal Role in the Federal System: The Dynamics of Growth. Advisory Commission on Intergovernmental Relations. Washington, D.C., May 1981. p. 17.

[6] U.S. National Science Foundation. Undergraduate Science, Mathematics and Engineering Education. National Science Board Task Committee on Undergraduate Science and Engineering Education. Washington, U.S. Govt. Print. Off., 1986. p. 14.

[7] Brinckerhoff, Richard, F. The Current Crisis in Secondary School Science Education - And One Response. National Association of Secondary School Principals Bulletin. Jan. 1982. p. 41.

C. FEDERAL FUNDING FOR SCIENCE AND ENGINEERING EDUCATION

There have been two principal agencies to support the improvement of science education, the NSF, and the Department of Education. The NSF has provided grants for the development of instructional materials, research in science education, the development of science education networks, and informal science education. The Department of Education has allocated the majority of its funds by means of block grants to State and local districts. These funds have provided support primarily for inservice training for teachers, with some for research and development of improved practices, fellowships for excellent teachers, science television programs for children, and research centers. The activities of these two Federal agencies are described as follows.

National Science Foundation

In the early 1970s, the NSF commissioned three national studies to evaluate the state of science, mathematics, and social studies. All of the studies findings were in concert in that there was a ". . . Steady deterioration of the conditions governing science education, at a time when our society needs a high-technology workforce."[8] These reports even noted that many teachers exhibited a "fear" of or aversion to science. A 1976 study of science and mathematics by the NSF portrayed a bleak picture of the state of science and science teaching at the precollege level.[9]

The report found that only 34 percent of the Nation's high schools required students to take more than one year of science or math.[10] The majority of the students acknowledged that they avoided taking more science courses than were required--and many were not required. In addition, it was found that more than half of the approximately 60 percent of high school students going to college had no physical science or math beyond algebra.[11]

Federal funding for science education began to decline in the 1980s. Science education support in the NSF, located in the Science Engineering Education Directorate (SEE) decreased from $61.3 million (46.1 percent of NSF's budget) in fiscal year 1959 (two years after Sputnik) to $20.9 million (2.1 percent) in fiscal year

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[8] Marcuccio, Phyllis. Responding to the Economic Sputnik. Phi Delta Kappan. May 1983. p. 619.

[9] U.S. National Science Foundation. The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in the U.S. Schools. Washington, U.S. Govt. Print. Off., 1978

[10] Brinckerhoff, Richard F. p. 43.

[11] Ibid.

sector also were terminated because the selected school districts could no longer provide matching funds for the required materials. Science education programs became fragmented as schools grappled with such issues as tight budgets, declining enrollments, the back-to-basics movement, and the rise of the middle school concept.

In fiscal year 1981 the Reagan Administration abolished the SEE in the NSF on the grounds that additional science education assistance was either unneeded or was a State responsibility. The support for science education had been a major mission of the NSF since it began in 1952. NSF's educational programs, which totaled more than 50 percent of the agency's budget following the launch of Sputnik, no longer existed. Support for science education from the Department of Education also was greatly diminished. Fiscal year 1982 funding for the NSF science education programs received the lowest amount of support in 25 years--$20.9 million ($70.6 million had been appropriated in fiscal year 1981).[13] Although the NSF recognized problems existing in science education, it simultaneously encouraged private industry, scientific professional organizations, State and local governments, and other Federal agencies to make the necessary contributions for their resolution. Concern regarding the state of U.S. education in general and intense lobbying efforts and congressional actions led to restoration of Federal support for science education and the reestablishment of the SEE on October 1, 1983. Since 1983, the SEE budget has grown faster than that of the NSF as a whole.

NSF's fiscal year 1990 budget includes a total request of $347 million for education and human resources, an increase of $62 million over the fiscal year 1989 level.[14] Included in this budget is $190 million for SEE, an 11 percent increase over the fiscal year 1988 level. NSF director Erich Bloch has stated that these funds will help to improve the supply of science and technology personnel. Significant support also is proposed for various science and mathematics programs at the precollege, undergraduate, and graduate levels.

NSF's fiscal year 1990 budget gives increased emphasis to the precollege level. The fiscal year 1990 request for this level is $129 million, an increase of $10 million over the fiscal year 1989 level. According to NSF, existing programs, such as efforts to improve teaching of science and mathematics, will be augmented with enrichment activities for talented high school students. Special attention will be directed toward mathematics curriculum reform at the middle school level. The Presidential Awards for Excellence in Science and Mathematics, once limited to middle-and secondary-level teachers, will be expanded to include elementary-level teachers. The Young Scholars Program, designed to draw students to careers in science, mathematics, and engineering, will be expanded. In addition, programs will be established to provide

p. 14.

[13] Undergraduate Science, Mathematics and Engineering Education. p. 14.

[14] U.S. Library of Congress. Congressional Research Service. Science, Engineering, and Mathematics Precollege and college Education. Issue Brief No. IB88068, by Christine M. Matthews, Feb. 2, 1989 (continually updated). Washington, 1989. 15 p.

hands-on research experience in order to stimulate interests and increase the awareness of science and engineering careers.

NSF has proposed to improve the quality of undergraduate instruction by providing $104.9 million in FY90, a 62.9 percent increase over the fiscal year 1989 level of $64.4 million. New and expanded activities include: instrumentation and laboratory instruction; student research participation; faculty enhancement; and curriculum development in calculus and engineering. In addition, NSF proposes that both graduate and postdoctoral education will receive increased support. Approximately 19,300 graduate assistants, 4,200 postdoctoral associates, and 12,000 undergraduates are to receive support in fiscal year 1990. Interdisciplinary training opportunities in mathematics and biotechnology are to receive particular emphasis.

The Presidential Young Investigators program for new doctorates also will be expanded in fiscal year 1990. NSF support for this particular program would be approximately $42.4 million, providing support for 860 researchers.

NSF also plans to increase support for individuals and groups who have historically been underrepresented in the sciences. Bassam Shakhashiri, Assistant Director, SEE, stated that NSF will continue its commitment to address the needs of minorities in the sciences. He concluded that:

> There's a national need to use the talents of minority students to contribute to the next generation of scientific and technological discoveries, but not enough of these underrepresented students are making it. . . . Local programs have demonstrated that minority students can succeed in scientific and technical careers, but these programs have been few and far between, and often strapped for funds. We want to encourage greater local and regional efforts by offering support at the national level.[15]

A total of $58.7 million in fiscal year 1990 (up from $49.2 million in fiscal year 1989) has been proposed for programs to attract women, minorities, and the disabled to careers in science and engineering through scholarships, outreach efforts and opportunities to participate in research. A new Women in Engineering component of the graduate fellowship program would provide support for 80 new fellows.

NSF Comprehensive Regional Centers for Minorities will receive grants totaling up to $12 million over 5 years to support local efforts (colleges, universities, community groups, and local and State governments) to increase minority participation in the scientific and technical workforce.

As part of the Minority Research Centers of Excellence (MRCE) program initiated in 1986, NSF has proposed the establishment of six minority research centers to "address the continuing shortage of minority scientists and engineers needed to maintain U.S. preeminence in fundamental research." Two of the centers already in operation, located at Howard University and Meharry Medical College

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[15] National Science Foundation News, NSF PR88-48, Aug. 19, 1988, p. 2.

will each receive $5 million over a period of 5 years. NSF plans to support all six MRCEs for 5 years, at a funding level of $5 million for each center.

Department of Education

The Department of Education supports precollege science and mathematics through Title II of the Elementary and Secondary Education Act, as amended by P.L. 100-297 (prior authorization was under the Education for Economic Security Act. P.L. 98-377). The widespread national concern about the declining quality of mathematics and science programs in the Nation's schools and the concomitant decline in student performance on standardized tests contributed significantly to the enactment of these mathematics and science programs.

Title II provides, under formula, funds to State and local education agencies for programs to improve instruction in targeted subject areas--science and mathematics. The funds are used mainly for training and retraining teachers in the particular areas. The fiscal year 1989 appropriation for this program was $137.3 million.[16]

Under current law, the math/science education program of title II is intended to improve instruction in mathematics and science. Prior law included improvement of computer learning and foreign language instruction. Of the annual appropriation, 95 percent is to be allocated among the States, on the basis of the 5- to 17-year-old population and the previous year's Chapter 1 (compensatory education) State allocations. Prior law allocated 90 percent among the States solely on the basis of 5- to 17-year-old population.[17] Current law provides 4 percent of the annual appropriation to the Secretary of Education for programs of "national significance". Prior law dedicated 9 percent to this purpose.[18] Compared to prior law, current law increases the percentage allocated directly to local educational agencies (approximately 64 percent of the annual appropriation under current law, approximately 44 percent under prior law).[19] Current law specifies in greater detail the activities authorized for local educational agencies, e.g., recruiting minority teachers to mathematics and science, and training teachers in instructional uses of computers in these subjects. The Secretary is newly required to submit a summary of State and local program evaluations biennially to Congress.

P.L. 100-297, signed by President Reagan on April 28, 1988, also authorizes the Star Schools Program Assistance Act to support statewide or multi-state partnerships for remote education via telecommunications network. Among their activities, the partnerships are to increase the availability of courses in mathematics, science, and foreign languages in elementary and secondary schools. A focus would be placed on those schools with significant numbers of disadvantaged students or in

[16] Ibid., p. 13.

[17] Ibid.

[18] Ibid.

[19] Ibid.

those schools with limited resources (materials) and corresponding courses in selected subject areas. The 100th Congress appropriated $14.4 million for the Star Schools Program Assistance Act for FY89.[20]

[20] Public Law 100-297, Title IX, sec. 901-2303.

II. SCIENCE AND ENGINEERING CONCERNS

A. SUPPLY AND DEMAND FOR SCIENTISTS AND ENGINEERS

There has been increased concern by educators, scientists and the Government about the continuing decline in numbers of science and engineering majors among college students in the United States. While scientists and engineers comprise approximately 4 percent of U.S. workers, their contribution affects the entire U.S. economy.[21] Many students are not choosing mathematics and science related careers because they failed to take the necessary mathematics and science courses to enter technical careers after high school or major in mathematics and science in college. Freshmen interest in science majors has declined by more than 30 percent in the past 20 years, with the most significant decrease occurring in the mathematical and physical sciences.[22] Specifically, interest in engineering has decreased by 25 percent since 1982, while interest in computer science has dropped by more than 66 percent in the past 4 years.[23] Harold J. Raveche, president, Stevens Institute of Technology, estimates that it takes approximately 10,000 high school students expressing an interest in a science or engineering major to generate a minimum of 20 doctorates in those disciplines.[24] Presently, 30 percent of the baccalaureate science and engineering graduates enter full-time graduate study, with only 50 percent of science and engineering doctoral candidates ever completing their doctorate.[25] Slight improvement in this retention rate could increase the number of scientists and engineers in the workforce.

A report prepared by the Task Force on Women, Minorities, and the Handicapped in Science and Technology, Changing America: The New Face of Science and Engineering, states that:

> Since the early 1980s, the proportion of U.S. freshmen choosing science and engineering majors in college has been wobbling downward. The drop has been little noticed because many foreign students have been enrolling in these fields; in addition, colleges have been making up total enrollments with older and part-time students who tend not to

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[21] U.S. National Science Foundation. Science and Engineering Indicators - 1987. Washington, U.S. Govt. Print. Off., 1987. p. 217.

[22] The American Freshmen: National Norms for Fall 1987. The Higher Education Research Institute, University of California, Los Angeles. Dec. 1987. p. 6.

[23] Ibid.

[24] Fowler, Elizabeth, M. Careers: Attracting Students to the Sciences. New York Times, May 3, 1988. p. O26

[25] U.S. Congress. Office of Technology Assessment. Educating Scientists and Engineers: Grade School to Grad School. Washington, U.S. Govt. Print. Off., 1988. p. 2.

> graduate in science and engineering. If these trends persist, America will graduate fewer U.S. bachelor degree holders and subsequently, even fewer Ph.Ds in science and engineering.[26]

The Task Force report concludes that emphasis should be placed on improvements to inspire enthusiasm and interest for science and mathematics for all students, primarily in the kindergarten through eighth grade (K-8) educational pipeline.

The United States is also losing a significant number of its research scientists to, among other things, retirements, corporate mergers, and reductions in corporate research and development (R&D). During a one-year period, 1987-1988, approximately 14,280 research scientists with more than 25 years' experience left the workforce.[27] This decline of 2.4 percent might possibly be the largest one-year loss ever.[28]

The scientific personnel pool is limited not only by the shortcomings of the educational system but also by the demand in the job market--a demand that is determined by a confluence of factors--economy, technological changes, and government priorities, which can have pervasive effects on the economy and the magnitude of R&D activities. The Bureau of Labor Statistics (BLS) estimates that jobs in the scientific fields will increase approximately 27 percent to the year 2000.[29] Military and private R&D is expected to require 13 percent more physical scientists, about 24,000 jobs, by the year 2000, primarily in the fields of laser research and high-energy physics.[30]

While the job prospects for physicists depend significantly on governmental priorities, the BLS predicts that the majority of physicists employed during the 1960s will retire, creating positions for new Ph.Ds. The job outlook for mathematicians, also, for the most part employed by the U.S. Government (primarily the Department of Defense) is influenced to a large extent by defense spending.

The NSF reports an estimated shortfall of approximately 700,000 science and engineering graduates for the next five years.[31] An OTA report maintained that concerted efforts by the Federal Government and by schools and colleges might avert an expected shortage of scientists and engineers. The report states that:

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[26] Changing America: The New Face of Science and Engineering. Interim Report. The Task Force on Women, Minorities, and the Handicapped in Science and Technology. Washington, D.C., Sept. 1988. p. 11.

[27] R&D 2000 Update. Newsletter of R&D Magazine. July 1988.

[28] Ibid.

[29] Walker, Wendy. Study Sees Big Leap in Science Jobs by 2000. The Scientist. June 13, 1988. p. 21.

[30] Ibid.

[31] U.S. National Science Foundation. Educational and the Professional Workforce. Mosaic, v. 18, Spring 1987. p. 12.

> The Federal Government may need to play a more active role. Rather than trying to direct market responses, policy can aim to prepare a cadre of versatile scientists and engineers for research and training careers, invest in an educational system that creates a reservoir of flexible talent for the work force, and ensure opportunities for the participation of all groups in science and engineering.[32]

B. DEMOGRAPHICS AND SCIENCE AND ENGINEERING TALENT POOL

Any attempts to address the expected shortfall of more than 560,000 science and engineering personnel by the year 2020 (estimate of the Task Force on Women, Minorities, and the Handicapped in Science and Technology) would be expected to recognize the demographic changes that are eroding the science and engineering workforce.[33] By the year 2000, 85 percent of the new entrants into the workforce are projected to be minorities and women, and minority groups are projected to constitute the majority of the population in 53 major cities.[34] However, today, a smaller proportion of minorities age 18 to 24 than of non-minorities has graduated from high school, and the college-going rates for those minorities who do graduate also is lower than those for non-minority high school graduates.

As a group, minorities, particularly blacks and Hispanics, have traditionally been underrepresented in the science and engineering disciplines compared to their fraction of the total population. Although there has been an increase in the participation of minorities in the science and engineering disciplines at the undergraduate level, it is over such a small base that the significance is muted. Presently, blacks and Hispanics are 25 percent of the precollege level, and, by the year 2000, they will comprise 47 percent (this change has already occurred in California, Texas, and New Mexico).[35] These demographic issues may affect the development of the scientific and engineering workforce and consequently, the conduct of R&D in the 21st century. The role of minorities in the sciences is no longer viewed as just a proportional representation issue but also one to meet the demand of a scientific and technical workforce. There is likely to be a need to expand and diversify the Nation's science and engineering workforce at all levels.

Concomitant with the underrepresentation and the recent downturn in their participation, blacks' and Hispanics' "persistence rate" (continuing in the program until graduation) in the sciences has been 29 percent as compared to the national

[32] U.S. Congress. Office of Technology Assessment. Educating Scientists and Engineers: Grade School to Grad School. Washington, U.S. Govt. Print. Off., 1988. p. 1.

[33] Changing America: The New Face of Science and Engineering. p. 11.

[34] Workforce 2000. Prepared by the Hudson Institute for the U.S. Dept. of Labor. Washington, U.S. Govt. Print. Off., 1987. p. 95.

[35] Changing America: The New Face of Science and Engineering. p. 11.

total of 79 percent.[36] Poor preparation in science and mathematics is said to be a major factor limiting the appeal of science and engineering to these groups and increasing attrition among those who do study the sciences. In 1986, U.S. colleges and universities awarded 18,792 Ph.Ds in science and engineering, 12,572 went to U.S. citizens.[37] Of those awarded to U.S. citizens, 1.9 percent (237) were awarded to blacks, 2.1 percent (263) were awarded to Hispanics, and less than 1 percent (49) were awarded to Native Americans.[38]

The class of 2000 has just started elementary school. Both short and long term investments may be needed to address the possible shortages and to expand and diversify the Nation's science and engineering workforce at all levels. A short-term approach could be to invigorate the current science and engineering workforce by reducing the attrition of undergraduate and graduate students, which would increase the pool of employable scientists and engineers within a few years. A long term strategy could entail enlarging the base of potential scientists and engineers by working with schools and colleges, children and teachers, to enhance elementary and secondary mathematics and science curriculum.

Some in their scientific community, however, conclude that the projected shortages in science and engineering personnel will not occur. They charge that career choices and market forces are more indicative of the future supply of scientists and engineers than are demographics determinants. They point out that past predictions of long-term shortages and surpluses have failed to materialize. Alan Fechter, executive director, Office of Scientific and Engineering Personnel, National Academy of Sciences stated that debate should not focus on whether there is a projected shortage, but on the " . . . nonwhites and nonmales, the numbers of foreign nationals and the numbers of women and minorities in science and engineering. There is an excess of some and a scarcity of others."[39]

C. OPTIONS TO IMPROVE SCIENCE AND ENGINEERING EDUCATION PROGRAMS

Precollege science and mathematics instruction has an important relationship to the future supply of U.S. scientific and technological personnel. The quality of instruction--the strengths and weaknesses of the instructors regarding their scientific knowledge combined with their attitudes concerning the importance of science instruction--has considerable influence on student interest toward and perceptions about science and technology. However, many are concerned that the educational pipeline, from kindergarten through the doctorate level, is failing to educate the

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[36] Science, Engineering, and Mathematics Precollege and College Education. p.6.

[37] U.S. National Science Foundation. Science and Engineering Doctorates: 1960-86. Detailed Statistical Tables. Washington, 1988. p. 7, 29.

[38] Ibid., p. 68, 73, 76.

[39] U.S. National Science Foundation. Education and the Professional Workforce. Mosaic, v. 18, Spring 1987. p. 15.

scientifically literate and mathematically knowledgeable workers required to meet future demand. Paul E. Gray, president, Massachusetts Institute of Technology, maintains that: "Our educational system has produced generation after generation of young people who are ignorant in science and incompetent in mathematics.[40] The majority of high schools in the United States do not require students to meet widely accepted standards of mathematics and science as recommended by the National Commission on Excellence in Education. Not only are U.S. students said to be inadequately prepared in science and mathematics, but those who are trained in these disciplines are seen as not prepared well enough to compete with their foreign counterparts. Most major assessments of science and mathematics achievement conducted in the past few years indicate that U.S. students have performed less well at the precollege level (grades K through 12) than students from Japan, West Germany, France and the United Kingdom. The 1985 Second International Mathematics Study, published by the Department of Educations's National Center for Education Statistics, found that among 20 industrialized and less-developed nations, U.S. students ranked 8th in statistics, 10th in arithmetic, 12th in algebra, 16th in geometry, and 18th in measurement.[41] Japanese students ranked first in all five categories. The 1988 publication of the International Association for the Evaluation of Educational Achievement, Science Achievement in 17 Countries: A Preliminary Report, found that U.S. students studying biology scored below students from the other 16 countries.[42] In chemistry, only students from Canada and Finland scored below U.S. students.[43] And in physics, Canada, Finland and Sweden were the only countries receiving a lower ranking in student performance than the United States.[44] The data from this particular study showed slight improvements from the first international study in 1970.

Significant problems with the Nation's elementary and secondary school systems were noted in A Nation at Risk: The Imperative for Educational Reform, which, it reported, have not experienced significant improvements since the 1970s.[45] There remain, according to the report, widespread shortages in qualified math and science teachers at the precollege level, with pervasive misassignment of teachers in selected school districts. In addition to concern about the performance of U.S. students in science and mathematics, the quality of science instruction and the

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[40] Gray, Paul E. America's Ignorance of Science and Technology Poses a Threat to the Democratic Process Itself. The Chronicle of Higher Education. May 18, 1988. p. B1.

[41] U.S. Dept. of Education. Second International Mathematics Study. National Center for Education Statistics. Washington, U.S. Govt. Print. Off., 1985. p. 5.

[42] Science Achievement in Seventeen Countries: A Preliminary Report. International Association for the Evaluation of Educational Achievement. New York, 1988. p. 3.

[43] Ibid.

[44] Ibid.

[45] U.S. Dept. of Education. A Nation at Risk. National Commission on Excellence in Education. Washington, U.S. Govt. Print. Off., 1983. 65 p.

content of the science courses have been found to be major problems at the precollege level. One charge is that science being taught in the schools does not reflect contemporary ideas in science and mathematics. Science courses are often said to need more relevance and meaning and to be developed in the context of the technical sophistication demanded by the future workplace.

Suggestions have been made for both incremental improvement of the K-12 science educational system and for radical restructuring of the curriculum. The concern for improvement is for all levels of education, but focused primarily on the K-12 level, because it is at this critical point when predilections and biases toward science and math begin to be developed. Proposals that have been offered for improvement of the educational system include:

(1) changing certification requirements to allow engineers, physicist, and mathematicians to become certified teachers in grades K-12;

(2) identifying unified principles across the sciences and considering alternatives to current disciplinary organization;

(3) providing specialized school settings that emphasize mathematics and science;

(4) providing more hands-on learning for the students and exploring better ways to achieve experiential science learning;

(5) integrating technology into science and mathematics courses; both as a tool and as a subject of study;

(6) matching instruction and learning environments to students of different ages and backgrounds; and

(7) generating greater cooperative support from universities by instituting student cooperative programs, providing staff members as adjunct faculty, and donating funds and equipment to laboratories. [46]

Many believe that a restructured educational system should not concentrate merely on the best science and math students at the K-12 level, but should also include broadening the pool of students, whether or not they go to enter the science and technology occupational pipeline. Bassam Z. Shakhashiri, assistant director, SEE of the NSF maintains that fostering an appreciation for science and technology in nonscientists is important for ensuring a supportive environment for science. Shakhashiri stated that:

> In my opinion, the situation we face now in this country is more critical and more consequential than what we faced in the immediate

[46] Knapp, Michael S., Stearns, Marian S., St. John, Mark, and Zucker, Andrew A. Prospects for Improving K-12 Science Education from the Federal Level. Phi Delta Kappan. May 1988, p. 679.

post-Sputnik era . . . It's the education in science and in technology of the nonspecialist that we have to pay attention to.[47]

The reality is that the need for building the math and science skills of students at the precollege and college level is beyond the abilities of many State and local governments. Presently, according to one source, the 600 largest school districts, which enroll 40 percent of all public school students, are unable to raise the necessary resources (primarily through property taxes) to bring their schools to basic standards.[48] A 1987 report prepared by the National Governor's Association Center for Policy Research concluded that improving the precollege science curriculum, increasing the quantity and quality of science teachers, and expanding the pool of undergraduates to study science and engineering were integral to improving the Nation's scientific resources.[49]

[47] Zurer, Pamela S. Improved Science Education is Goal of Revived NSF Education Unit. Chemical and Engineering News. May 16, 1988. p. 31.

[48] White, Jack E. Education: Getting What you Pay For. Time, Sept. 12, 1988. p. 32.

[49] The Role of Science and Technology in Economic Competitiveness. Prepared by the National Governors' Association Center for Policy Research and Analysis and the Conference Board for the National Science Foundation. Washington, D.C., Sept. 1987. 51 p.

III. SCIENCE AND ENGINEERING PERSONNEL IN THE DEPARTMENT OF DEFENSE

There remains debate as to whether or not the Nation's recent defense buildup (the third major buildup since 1950) might cause a "brain drain" on scientists and engineers from the civilian sector and whether this drain has an adverse effect on the Nation's competitiveness. The Office of Management and Budget estimates that support for defense research and development (R&D) between fiscal years 1981 and 1989 increased approximately 71 percent in real dollars while nondefense R&D support declined about 10 percent in real dollars during that same time period.[60] These R&D spending patterns have been thought to portend a shift in technical talent, "draining" scientists and engineers from the civilian sector and causing U.S. commercial companies' deficiencies in the talent they need for competition with foreign industries. However, a 1986 report prepared by the National Academy of Engineering, The Impact of Defense Spending on Nondefense Engineering Labor Markets, maintained that the defense buildup is not draining away scientists and engineers from the civilian sector.[61] The report states that:

> Although the current demand for engineering services is high, evidence drawn from a variety of sources does not suggest pervasive or serious industrial shortages. However, problems may exist in particular fields requiring highly specific training, such as optics, and shortages of engineering faculty have been well documented.[62]

The report noted that approximately 20 percent to 30 percent of the Nation's engineers traditionally go into defense related work and that this pattern was not expected to change dramatically.[63] Cyclical peaks and valleys are characteristic of engineering fields and in periods of high demand, it is likely that many of those holding a baccalaureate degree would immediately enter the job market. In periods of low demand, many baccalaureate holders would possibly enter graduate school. While the report concluded that there should not be grave concern about a draining of technical talent or "engineering bottlenecks" as a result of the present defense buildup, it was reluctant to make projections about demands in the future.

> [I]n the past, the government invested more heavily in subsidizing the education of talented students who wanted to become engineers

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[60] U.S. Library of Congress. Congressional Research Service. Research and Development Funding: FY 1990. Issue Brief No. IB89040, by Michael E. Davey, Coordinator, Feb. 15, 1989 (continually updated). Washington, 1989. 15 p.

[61] The Impact of Defense Spending on Nondefense Engineering Markets. A Report to the National Academy of Engineering. National Research Council. Washington, D.C., 1986. 91 p.

[62] Ibid., p. 18.

[63] Ibid., p. 8.

through such programs as the National Defense Education Act. Because these subsidies are smaller now, and because the number of engineering graduates is declining, the report did not rule out the possibility for bottlenecks in the future.[64]

Presently, data indicate that the DOD employs approximately 108,000 scientists and engineers out of a total science and engineering workforce of 3 million, or about 3 percent.[65] More than 14 percent of U.S. scientists and engineers are either employed directly by the DOD or engaged in DOD related work.[66] The scientific and engineering workforce constitutes more than 15 percent of the defense industry employment.[67]

A 1988 report prepared by the Defense Manpower Data Center, however, presents a somewhat bleak picture of future science and engineering concerns within the DOD. The report stated that:

> . . . S&T [science and technology] employment has increased by more than 25,000 from December 1979 to June 1988, a 41 percent increase. If skills shifts continue as projected, we can expect a 10 percent increase in the number of S&T personnel required by the year 2000. this trend will be further exacerbated by turnover of our S&T personnel. Even assuming a non-growth environment, and absent any major initiatives to improve retention, DOD can reasonably expect to have a loss of 7,000 to 10,000 S&T personnel a year due to turnover. Currently, we are able to hire entry level replacements of engineers,but replacements of scientists have been declining over the last several years. These replacements will be difficult to recruit in the highly competitive and tighter labor market of the year 2000 in all S&T area, but especially in the areas of biomedical and computer science. Due in part to its compensation and benefits programs the Federal government will become increasingly noncompetitive in an increasingly tighter labor market, at least through the year 2000.[68]

A particular item in the defense fiscal year 1983 budget, the Strategic Defense Initiative (SDI) has focused increased attention on science and engineering personnel in the DOD. Some critics have charged that the large demand for highly skilled scientists and engineers by the SDI would have negative consequences on the national economy and would serve as " . . . a talent sponge that would soak up the

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[64] Marshall, Eliot. The Pentagon is Not Eating Engineers. Science, Nov. 7, 1986. p. 664.

[65] Competition for Human Resources in Science and Engineering in the 1990s. Proceedings of a symposium of the Commission on Professionals in Science and Technology, Oct. 11-12, 1987. p. 48.

[66] Ibid.

[67] Ibid.

[68] Internal DOD document.

best and brightest graduates."[59] While some counter that anecdotal evidence has not found validity in that assertion, others acknowledged that optics, an area of considerable interest for SDI, might experience a shortest of trained personnel. However, even this shortage is not expected to continue because many engineers are moving into optics from other fields.[60]

A 1987 report prepared by the Council on Economic Priorities, Star Wars: The Economic Fallout, proposed that the SDI will have an adverse effect on the Nation's science and engineering employment, export market, and technological leadership.[61] The report found that:

> SDI used an estimated 9,000 engineers, scientists and technicians in 1986. The figure will triple by 1991 to roughly 28,500 if current budget projections for the program hold true. Barring a return to rapid economic growth and an acceleration of military spending in the next five years, this level of demand for technical talent by SDI should not provoke shortages in qualified personnel in industry or other government programs. But, once SDI proceeds to the point of development and deployment, the potential for shortages increases dramatically.
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> Full-scale deployment of an SDI system will require between 130,000 and 180,000 scientists and engineers per year over a ten-year period. This demand is about twice the number of specialists required per year during the Apollo program's most intense period of shortages. The hypothetical SDI deployment would require about 5.1 percent of the scientific and engineering talent pool between 2001 and 2010. In comparison, the NASA effort required 4.1 percent on the average between 1961 and 1968.[62]

The Council's report maintained that the SDI defense buildup would divert scarce resources and technical talent to areas that have minimal benefit to the civilian economy and that the commercial market would experience considerable drain on the most talented scientists and engineers. The present level of demand for scientific and technical personnel by the SDI is not expected to provoke shortages in qualified personnel in Government programs or in the private sector. However, once the SDI reaches the point of being operational, some assert that the potential for shortages in personnel increases markedly.

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[59] Ibid., p. 664.

[60] Ibid.

[61] Star Wars: The Economic Fallout. Council for Economic Priorities. Cambridge, MA, 1987. 234 p.

[62] Nimroody, Rosy. Star Wars: The Economic Fallout. Council on Economic Priorities. Research Report. Nov./Dec. 1987. CEP Publication N87-11. p. 3.

IV. DEPARTMENT OF DEFENSE SCIENCE EDUCATION INITIATIVES

A number of education programs in the DOD contribute toward increasing the participation of all categories of individuals to scientific and technical fields. Many of the current investments of the DOD attempt to address the cumulative and dramatic impact that the changing workforce between now and the year 2000 is projected to have on the Department's mission and performance. This section describes some of the significant programs currently being used by the DOD components at the precollege, undergraduate, and graduate level. There does not appear to be specific authorization for these programs. Rather, they are implemented through general authorizations and such means as general personnel directives.[63]

A. PRECOLLEGE PROGRAMS

1. Department of Defense Science and Engineering Program

The Department of Defense Science and Engineering Program began in 1979 in Washington, D.C. in area Army and Navy laboratories. This program is designed to have special appeal to minorities and women who are considering science and engineering as a profession. The major objective of this apprenticeship program is to identify talented students and to encourage them to pursue careers in science and technology by providing them with an eight week working experience in a science or engineering environment. Since its beginning, the program has expanded to include other Army, Navy, Air Force and DOD components and has involved the participation of all of the DOD laboratories. This program has served approximately 1,000 students each summer for the last nine years.

2. Science, Technology and Research Students

The Science, Technology and Research Students (STARS) program is targeted for junior high students. It provides a three day intensive program to encourage students to enter a science or technical field. The program instructs the student in high school course selections with emphases on the requisite science and math course for entry into science and technology studies in college.

3. Adopt a School and Tutorial Programs

The Adopt a School and Tutorial Programs allow variability in approaches to encourage students, primarily women, minorities and the handicapped, to pursue studies in math and science. Various DOD components participate in these programs through local schools, and provide tutoring and mentoring to students at an early age to stimulate interests in science and technology within the Department of Defense.

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[63] Interview, Apr. 13, 1989, with Jeanne Carney, staff specialist, Dept. of Defense, Office of the Under Secretary of Defense Research and Engineering.

4. Summer Aid and Stay-in-School Programs

The goal of the Summer Aid and Stay-in-School Programs is to employ financially needy students so that they may continue or resume their education. The program is restricted to students who are at least 16 years old and who are enrolled or accepted for enrollment as full-time students in high school, vocational school or institutions of higher learning. These are primarily cyclical programs in which the students work in DOD facilities during summer and holiday periods and up to 20 hours during the regular school year. Many of the activities within the parameters of these programs have been used to stimulate interest in science and technology and to provide an opportunity to establish mentor relationships between employees and students. The Army, Navy and Defense Mapping agencies have been active in these programs.

5. The Army Research Office Junior Science and Humanities Symposium

The Army Research Office Junior Science and Humanities Symposium (JSHS) program is designed to:

(1) promote research and experimentation in the science, mathematics and engineering at the high school level;
(2) Search out talented youth and their teachers, recognize their accomplishments at symposia and encourage their continued interest and participation in the fields of science, mathematics and engineering; and
(3) increase the number of future adults capable of conducting research and development.[64]

The principal source of funding for this symposium program is the Army Research Office, with some matching funding by participating academic institutions.

As designed, the JSHS holds 46 regional symposia each year at colleges and universities each year. The two to three day meetings are attended by selected high school students and science teachers. The symposia include, among other things: 1) presentations of papers by students describing their research; 2) presentations by scientists of current research appearing in the professional literature; and 3) laboratory site-visits to observe professional researchers at work. Approximately 8,000 students participate annually. From the each regional symposium, five students are chosen to attend the National JSHS held at either the United States Military Academy in West Point, New York, or at another university. From that meeting, seven students are selected to attend the London International Youth Science Fortnight, London England.

[64] Internal DOD document, Nov. 1988.

6. The Army Research Office of Naval Research Uninitiated Introduction to Engineering Program

The Army Research Office of Naval Research Uninitiated Introduction to Engineering Program (UNITE) is designed to provide special instruction in science and mathematics for socially and economically disadvantaged high school students. Approximately 215 students each year attend four to six week summer sessions at selected colleges and universities. Both the Army and Navy support these programs along with the participating institution. DOD laboratories near program locations also participate by introducing these students to science career opportunities in DOD related R&D.

7. The Army Research Office Computer Related Engineering and Science Studies Program

The purpose of the Army Office Computer Related Engineering and Science Studies Program (CRESS) is to provide opportunities for highly motivated and gifted high school students to study computer science. Programs are held for a four week period during the summer at two universities--North Carolina State University and the University of Miami. The Army Research Office and the universities support the program which is managed under contract by the Academy of Applied Science.

The CRESS programs are directed by the electrical engineering staff at the participating universities. The students receive instruction and laboratory work in logic, microprocessing, structure computer languages, and robotics. In addition, the students are provided information about Army's interest in computers and computer-related fields.

Students participating in the program must be nominated by their high school science teachers and also selected by the universities. Prerequisites include completion of Algebra I and Algebra II. Approximately 50 students participate each summer, of whom half are minority.

8. PreFreshman Engineering Program

The Defense Mapping Agency, along with the city of San Antonio, Texas, participate in the PreFreshman Engineering Program (PREP) as part of the President's Partners in Education Program, the DOD Partnerships in Education Initiatives and the Defense Mapping Agency's affirmative employment program. PREP exposes precollege level students to career opportunities in mapping, charting and geodesy. Its major purpose is to identify talented junior and senior high school students of the Greater San Antonio area who are potential scientists and engineers and to provide them with the needed reinforcement and guidance to pursue studies in science and engineering upon entering college.

An academically intense eight week program focuses on the development of abstract reasoning skills, problem solving skills and career opportunities in engineering and science. Since 1979, approximately 2,000 students have completed at least one summer in PREP; 78 percent have come from minority groups underrepresented in science and engineering, and 48 percent have been women.[65] Financial and full-time inkind manpower staff support comes from local, State, and national colleges and universities; military commands; Government agencies; private industry; and local school systems. A 1987 follow-up survey of PREP participants found that approximately 70 percent attended college, and of those, 50 percent enrolled in science and engineering programs.[66]

9. Grow Your Own Programs

Conducted by the National Security Agency, Grow Your Own Programs are designed to train high school seniors primarily in nontechnical, intelligence-specific career fields. Eligible high school seniors enter specifically designed technical training programs which differ in length but are all structured toward developing skilled technicians in various fields, including computer operations and engineering technology. Participation varies widely from year to year depending on fluctuations in operational requirements.

10. High School Work Study Program

The High School Work Study Program, also of the National Security Agency, recruits high school juniors for part-time work during their senior year in a variety of disciplines, with a majority performing computer operations. Approximately 150 students are employed under this program.

B. UNDERGRADUATE PROGRAMS

1. Cooperative Education Program

The DOD has made extensive use of the Cooperative Education Program (CO-OP). The primary purpose of the CO-OP is to provide rewarding work experiences, coupled with a technical or professional education, that results in "superior" full-time employees. For the most part, the program is used to attract entry level professionals in science and engineering. The departments of the Army and Air Force, Defense Mapping Agency and the National Security Agency have decentralized, locally funded and managed programs. The Department of the Navy has a centrally funded and managed program, as well as a decentralized, locally funded and managed program.

The Department of the Army has active CO-OP programs for graduate, baccalaureate and high school students. As of August 31, 1988, Army data indicated that there are 21 graduate school participants, 702 baccalaureate level participants, and 163 high school participants.[67]

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[65] Internal DOD document, Nov. 1988.

[66] Ibid.

[67] Internal DOD document, Oct., 1988.

Since 1976, the Department of the Navy has used the CO-OP program as a source of employees with mathematics, science and engineering skills. The Navy's centralized CO-OP program is funded and managed by the Chief of Naval Operations, and the decentralized approach is funded and managed at the field activity level. The Navy's programs comprise mainly minorities and women.

The Air Force has used the CO-OP program primarily to increase the development of future science and technology employees at many of its bases. For example, the Aeronautical Systems Division at Wright-Paterson Air Force Base, Ohio, has approximately 100 students enrolled in its science and technology program.[68]

The National Security Agency has significantly increased the use of the CO-OP program in the past 10 years, and it presently includes 260 positions, mainly in engineering, computer science and mathematics. Data indicate that the retention rate is approximately 80 percent.[69] The 1988/1989 recruitment schedule includes eight historically black colleges and universities, four primarily Hispanic and Native American colleges, and one university for hearing-impaired students.[70]

The Defense Mapping Agency makes limited use of the CO-OP program.

2. Department of the Army Scientific and Engineering Reserve Officers Training Corps CO-OP Program

The purpose of the Department of the Army Scientific and Engineering (DASE) Reserved Officers Training Corps (ROTC) CO-OP program is to encourage those students majoring in science and engineering to join the Reserve Officers Training Corps (ROTC), and to retain graduates first as military officers and second as civilian employees. It provides work experience as a supplement to educational experience, and funding for science and engineering students to remain in college while promoting the DOD as a "high tech" employer. Tuition assistance of up to $5,000 a year is available for students who are not ROTC scholarship holders.

Internal documents indicate that as of August 1988, the Army had 43 participants, of which 10 (23 percent) were minorities and seven (16 percent) were women.[71]

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[68] Ibid.

[69] Internal DOD Document, Nov. 1988.

[70] Ibid.

[71] Ibid.

3. Undergraduate Training Program

The Undergraduate Training Program was established in 1986 by P.L. 99-569.[72] The legislation provides full academic scholarships, salary at the Government grade 02 level, and summer employment for high potential high school students who are pursuing bachelor's degrees in engineering, computer science, mathematics, and other National Security Agency (NSA) critical skills. This particular program is intended primarily for, but not restricted to, minority students. After graduation, the students are required to serve an equivalent number of years of full-time employment at the agency.

The NSA currently has 20 participants, of which 15 are minorities and 1 is handicapped.[73]

4. Air Force University of Dayton Reentry Program

The Air Force University of Dayton Reentry Program is designed to recruit non-Federal employees nationwide who have earned a baccalaureate or advanced degree in mathematics, physics, or the technical sciences to qualify as electrical engineers. This is a 12-month program requiring completion of 39 semester hours of curriculum in electrical engineering with additional course work offered in software for electronic engineering conversion and electrical and magnetic field theory. Participants in the program receive a bachelor of science degree in electrical engineering and incur a three year commitment to the Air Force Logistics Command (AFLC). Tuition is paid by the AFLC and the students are offered Federal employment when all electrical engineering requirements are satisfied.

Twenty-eight students are selected for classes beginning in April of each year. The success of this program is reflected in that 141 students out of a total of 144 who have graduated since 1982 have been hired by the AFLC.[74]

C. GRADUATE LEVEL PROGRAMS

1. The Office of Naval Research Graduate Fellowship Program

The Office of Naval Research, through the American Society for Engineering Education, operates the Naval Research Graduate Fellowship Program. It awards three-year fellowships for study and research leading to a doctorate degree. Awards are made in science and engineering disciplines important to naval technology. Disciplines that have been represented to date include: electrical engineering, applied physics, mathematics, naval architecture and ocean engineering, computer science, aerospace and mechanical engineering, cognitive and neural sciences, biological and biomedical science, and materials science. In addition, fellowships are awarded for

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[72] 5 U.S.C. 505.

[73] Internal DOD document, Oct. 1988.

[74] Internal DOD document, Nov. 1988.

study in oceanography, with special designation "Secretary of the Navy Fellowships in Oceanography".

The fellowships are available at doctorate-granting institutions in the United States. Fellows are encouraged to continue their studies during the summer in Navy laboratories. Approximately 150 fellows are supported each year.

2. The Air Force Laboratory Graduate Fellowship Program

The Air Force Laboratory Graduate Fellowship Program is one component of the Air Force University Research Initiative and supports U.S. citizens for doctoral studies in areas designated by Air Force laboratories. Disciplines represented in this program include: electrical engineering, mechanical engineering, aeronautical and astronautical engineering; biomedical engineering; chemical industrial and civil engineering; physics; computer modeling; computer science; toxicology; chemistry; mathematics; metallurgy; life science; biophysics; and behavioral sciences. The program is managed under contract by Universal Energy Systems. Fellowships are for three years. Approximately 50 fellows will be receiving support in fiscal year 1989.[75]

3. The Air Force Graduate Student Research Program

The Air Force Graduate Student Research Program is designed as an adjunct to the summer Faculty Research Program. It provides research funds for graduate students to work at Air Force facilities with a professor holding a current summer Faculty Research appointment, or one who is a Resident Research Investigator. Applications have been made available for graduate students who do not have a Summer Faculty Program supervising professor. In fiscal year 1988, 14 of the 113 students who participated in the program were from historically black colleges and universities.[76]

4. The Air Force Thermionic Research Initiative

The Air Force Thermionic Research Initiative (ATRI) program is centered around multidisciplinary research and education in microwave and millimeter wave tubes. Located at the University of California, Los Angeles, it is supported by the Air Force Office of Scientific Research with cosponsorship from the major U.S. tube companies. ATRI fellowships are awarded to U.S. citizens for graduate study and research leading to masters or Ph.D. degrees.

5. The Air Force Research in Aircraft Propulsion Technology Program

Initiated in 1982, the Air Force Research in Aircraft Propulsion Technology Program (AFRAPT) is designed to attract students for research in aircraft propulsion technology. It is conducted concurrently at five institutions with programs that lead to a doctorate degree: Massachusetts Institute of Technology and Purdue University

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[75] Ibid.

[76] Ibid.

in fluid mechanics and structures; Texas A&M University in structures; and Princeton University and Pennsylvania State University in combustion.

The AFRAPT is a cooperative arrangement with AVCO Lycoming, Detroit Diesel Allison, Garrett, General Electric, and Pratt and Whitney Aircraft. Participation in the program is restricted to graduating seniors who have been accepted for part-time employment by one of the companies and who have also been accepted for graduate study by one of the universities. Each student is considered a full-time, paid, research trainee of a participating university.

6. The Air Force Manufacturing Science Program

The Air Force Manufacturing Science Program is operated through the Air Force Wright Aeronautical Laboratories and the Air Force Office of Scientific Research. In the past, the program has had two university-based enters, one at Stanford University and one at the University of Michigan. Advisory boards for the centers represent industry, the universities, and the Air Force.

The students conduct research at the university-based centers or at the sponsoring company. Assistantship funding for the masters and doctoral programs is provided by the Air Force. This program is currently undergoing a reorganization.

7. National Security Agency Summer Program

The National Security Agency Summer Program is designed for graduate level and exceptional undergraduate students, computer scientists and mathematicians interested in summer employment. The main premise of the program is that when students are exposed to the "state of the art" research performed at an agency, they will be encouraged to seek full-time employment upon graduation.

The NSA ployed 65 applicants in 1987, and approximately 66 percent elected to return ull-time employment upon graduation.[77]

8. Research S vices of Students

The Defense Authorization Act of 1982, P.L. 97-86, established the Research Services of Students program.[78] The Secretary of Defense is authorized to: " . . . contract for the temporary or intermittent services of college students to provide short-term technical support at Defense research and development laboratorie."[79] Regulations implementing this statute wera incorporated into the DOD acquisition in 1983. The Army has made extensive use of this authority. The Army Medical Research and Development Command employs about 400 students and the Army Corps of Engineers, about 350 students, in their research laboratories each year. Participants are principally graduate students.

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[77] Ibid.

[78] 6 U.S.C. 603.

[79] Ibid., p. 1857.

V. OPTIONS TO INCREASE DOD'S ROLE IN SCIENCE AND ENGINEERING EDUCATION

At issue is whether or not there is a further role for the DOD in science education. Below are a set of options for congressional consideration in its oversight role concerning DOD's activities to help recruit, train, and advance a sufficient fully qualified scientific and technical workforce. Some of the identified options have relevance to broader science and engineering concerns, while others are specific to the existing structure of support for science and engineering education in the DOD. The options are presented here without analysis in depth and reflect a variety of perspectives.

How should the DOD mobilize the resources and professional participation required to affect science education significantly over a period of time? What programs should be implemented to broaden the pipeline of minority youth pursuing science, engineering and technology careers? Generally, recommendations directed toward improving science education activities or increasing the pool of all students entering science and technical fields would require an increase in resources. And, in the context of the overall DOD budget and the Federal budget deficit, any proposed increases would be expected to be controversial.

If Congress decides to implement any intervention programs to expand the DOD's current investments in science and engineering education, two things may be needed. In order to ensure that support for science education is allocated efficiently --whether it is decreased, maintained at the present level, or increased--improved methods of coordination among the Services and DOD components may be required. At the present, science education efforts in the DOD are characterized by considerable delegation to the Services and agencies. Congress could consider, in its fiscal year 1990 authorization bill for DOD, including language to require the Under Secretary of Defense for Acquisition to put the Director of Defense, Research and Engineering (DDR&E) in charge of all DOD science and engineering education programs (precollege, undergraduate, and graduate). One individual could be delegated with full authority for these programs and could take a proactive role in facilitating interservice coordination. Having the responsibility of science education programs placed with one individual could help to prevent duplication of efforts while simultaneously guarding against inadequacy of funding in any particular area. A centralized point of unified leadership and authority for science programs in the DDR&E could be expected to foster improved coordination with the Services and DOD components by strengthening and maintaining intervention methods and placing less of a burden on any one agency's constrained resources. In addition, increased systematic coordination may permit the Services and the DOD components to establish complementary goals and objectives for science and engineering education at all levels. Equally important, during the DOD authorization process, one person would be able to present to Congress a DOD-wide integrated picture of its various science education activities. However, the current system's multiplicity of inputs from the various services and agencies has certain advantages, such as allowing a wide range of expertise in program design so as to represent the various interests involved.

A second action that could occur before implementing or expanding any intervention programs would be a comprehensive review of all current DOD science and engineering programs. The review could include: (1) the amount of funding by the Services and the DOD components for all science and engineering programs; (2) the goals and objectives of the programs; and (3) coordination mechanisms currently in use (including documentation and evaluation of existing mechanisms. The review could also determine possible mechanisms for optimum coordination of the various programs. Centralization and increased coordination of science and education efforts could enable the DOD to place its current and newly initiated programs in the context of broader national concerns.

In addition to expanding the existing programs operating within the various components of the DOD, the following options for addressing the needs of science and engineering personnel could be considered.

(1) Establish a commission or advisory board among Federal agencies, academia, and private organizations to bridge the communities of interest in science and engineering education and place DOD efforts in the context of broader national concerns.

(2) Explore possibilities within the DOD dependents school systems for the enhancement of science, mathematics, and engineering preparatory educational programs. Use these schools to test NSF curricula and teacher training proposals.

(3) Increase the pool of retired military officers and civilian DOD personnel to serve as "adjunct" science teachers at the precollege level in order to extend and update the knowledge of the classroom teacher while encouraging more students to become interested in science and engineering.

(4) Identify initiatives that would provide current employees with educational opportunities leading to a degree in science, engineering and technical occupations.

(5) Increase funding for intervention programs. Costs for precollege programs in the DOD are currently $1,000 per year per student, undergraduate programs are $5,000 per year, and graduate fellowships amount to approximately $20,000 per student. Education costs at colleges and universities have been escalating for years, and this trend shows no sign of abating. Substantial increases for these intervention programs could be included in the budget appropriations or in the Five Year Defense Program.

(6) Provide incentives to DOD contractors to provide educational opportunities directly for support to local universities for assistance to K-12 for science and mathematics upgrade.

(7) Enhance financial aid packages to military personnel who choose science and engineering majors and who take advantage of military education assistance programs.

Many of these initiatives could be costly and expected to receive close scrutiny in times of significant budget constraint.

The projected shortage of science and engineering personnel both within the Department and the general workforce will likely affect the DOD. Congress may consider programs in the DOD and in related Federal agencies and private sectors, to increase the number of students choosing science and engineering careers. Because of the number of years it takes to "grow" a scientist or engineer, programs have been proposed at all levels of the education system--precollege, undergraduate, and graduate level. If Congress decides on a further role for the DOD in improving science education, DOD's effectiveness will depend on numerous factors, including available resources, and definitive leadership articulated within DOD's various components.