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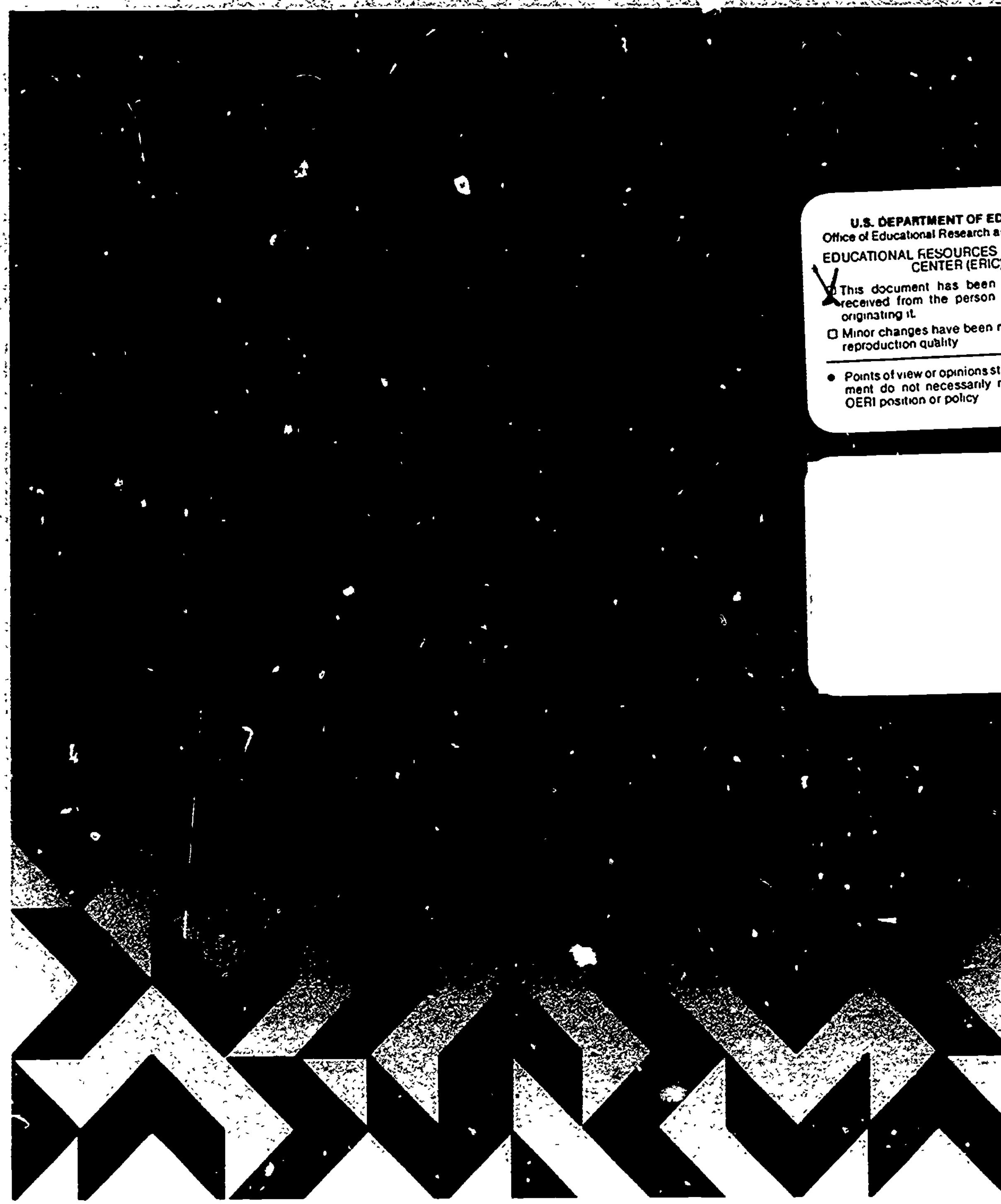
ABSTRACT

This volume was written to reflect an increased awareness of the complementary roles played by science and engineering research and engineering in creating both new knowledge and new technological products and processes. It was designed to provide a broad base of quantitative information about the structure and function of science and technology in the United States in order to inform national policymakers who must allocate resources to these activities. Many feel that it is essential to this process that policymakers understand indicators well enough to properly support basic research, applied research and development, innovation and education. Profiles include: (1) "Precollege Science and Mathematics Education"; (2) "Higher Education for Scientists and Engineers"; (3) "Science and Engineering Workforce"; (4) "Resources for R&D and Basic Research"; (5) "Academic R&D and Basic Research: Patterns of Performance"; (6) "Industrial Research and Technological Innovation"; (7) "International Markets for U.S. Technology"; and (8) "Public Attitudes toward Science and Technology." Appendices include statistical tables, contributors and reviewers. (CW)

# SCIENCE & ENGINEERING INDICATORS - 1987







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# Letter of Transmittal

*November 30, 1987*

My Dear Mr. President:

In accordance with Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended, it is my honor to transmit to you, and through you to the Congress, the eighth in the series of biennial *Science Indicators* reports, this time retitled, *Science & Engineering Indicators—1987.*

These reports are designed to display a broad base of quantitative information about U.S. science, engineering, and technology for the use of public and private policymakers in their decisions about these activities.

The actions of Government and industry in recent years demonstrate their recognition of the critical contributions of basic research and advanced technology development to our health, welfare, economic competitiveness, and national security. The quantitative analyses in this report portray these developments in some detail, thereby improving our understanding of the scientific and technological enterprise.

As in previous reports, basic information is provided on U.S. and comparative foreign trends in R&D support and performance, school science and mathematics, human resources for science and technology, technological innovation and trade in high-technology products, and public attitudes toward science and technology. New features of this report include a chapter on "Higher Education for Scientists and Engineers" and an "Overview" section that features the major findings of the report.

I and my colleagues on the National Science Board trust that this report will be of value to your Administration, to the Congress, and to those concerned with science and technology policy.

Respectfully yours,

Roland W. Schmitt
Chairman, National Science Board

The Honorable
The President of the United States
The White House
Washington, D.C. 20500

# Contents

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# Introduction

This volume is the eighth in the biennial *Science Indicators* series initiated by the National Science Board in 1972. The report has been renamed *Science & Engineering Indicators (S&EI)* to reflect an increased awareness of the complementary roles played by science and engineering research and education in creating both new knowledge and new technological products and processes.

The series provides a broad base of quantitative information about the structure and function of American science and technology in order to inform national policymakers who must allocate resources to these activities.

More specifically, our leaders and policymakers need to know what kinds, levels, and directions of national effort in science and engineering research and education are necessary in order to:

- Produce significant advances across a broad front in the understanding of natural and social phenomena (basic research);
- Foster vigorous inventive activity to produce continuing technological advances (applied research and development);
- Combine understanding and invention in the form of socially useful and affordable products and processes (innovation); and
- Assure an adequate supply of highly trained scientists and engineers to staff the Nation's businesses, schools, and government.

The science, engineering, and technology system is less easy to measure than other major functional areas of our society such as health, agriculture, or the economy. This is in good part due to the nature of its primary output—knowledge and ideas. People create, communicate, and carry ideas; and dollars support people. We can and do track people and dollars. But our methods for measuring science as a body of ideas and its connections with the social and economic order are still unsophisticated. Thus, our indicators remain—for now—largely measures of aspects of science and engineering *as sets of activities*, rather than as *particular bodies of knowledge*.

The elements of the science, engineering, and technology system in America are:

- The human resources, including mainly the working scientists and engineers themselves, but also their technical support and technical managers and entrepreneurs;
- The various organizational settings for the conduct of research and development and technical education;
- The substantive ideas and research methods and strategies embodied in large part in science and engineering literatures;
- The physical infrastructure, including research and teaching facilities and instrumentation with the most advanced capabilities;
- The necessary financial support for all of these elements; and
- Probably the least tangible, a cultural, economic, and legal context supportive of these efforts.

These elements and subelements, while easy to specify in principle, are difficult to describe in practice. Many problematic research issues are involved—for example, choosing definitions and information-gathering methods in terms of their costs and benefits. Even more critical are the problems of tracking and analyzing the interactions among the imperfectly measured elements—the dynamics of the system. Continuing investigation into these questions is a *sine qua non* of improved indicators, and the National Science Foundation (NSF) does provide modest funds for external research projects in this area. (See Program Announcement NSF 85-50.) Descriptions of projects currently under way are available in *Project Summaries: FY 1986* (NSF 86-313).

About one-half of the quantitative information in this report is generated by the national surveys and studies conducted on a continuing basis by the Division of Science Resources Studies (SRS). Detailed reports of these studies are listed in the Division's *Publications List: 1977-1987* (NSF 87-312).

In response to suggestions from a variety of sources, both the substance and format of *S&EI—87* have been modified from previous editions.

- The Overview section has been changed from a purely textual exposition to a set of graphic displays of the report's major findings, accompanied by short descriptive captions and references to the more extensive discussions in the chapters.
- A new chapter, "Higher Education for Scientists and Engineers," focuses on the education and training of scientists and engineers and the roles played by different kinds of higher education institutions.
- To provide more complete coverage of each major topic, the international comparative aspects of each topic have been integrated into the chapters. Significant international comparisons are presented together in the Overview section.
- A discussion of basic research in various settings has been added to the chapter on academic research.
- The chapter containing narrative discussion of selected advances in science has been discontinued on the grounds that these qualitative materials are more appropriately handled elsewhere.

*Science & Engineering Indicators—1987* is a collective effort, as can be seen in the following acknowledgments and in Appendix II. Overall responsibility for the report derives from the statutory charge to the National Science Board [Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended]. A special committee of National Science Board members provided oversight and guidance to the staff of the Science Indicators Studies Group of the Division of Science Resources Studies, who worked exclusively on the report and the related research. Other SRS members, as well as staff members from other NSF Directorates, aided in manuscript preparation. Numerous external expert reviewers and users helped shape and sharpen the indicators. Overall staff responsibility for the report was assumed by the Directorate for Scientific, Technological, and International Affairs.

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# Acknowledgments

The National Science Board extends its appreciation to the following members of the National Science Foundation (NSF) who provided primary assistance with the preparation of this report.

Organizational responsibility was assigned to the Directorate for Scientific, Technological, and International Affairs:

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Richard M. Berry, Directorate for Science and Engineering Education

Primary statistical and secretarial support was provided by Theodosia (Dottie) Jacobs, Vellamo Lahti, Eliza Hizell, and Rosa Queen, all staff members of SRS.

The Board expresses its deep regret at the passing of Dr. Robert R. Wright on July 13, 1987. The Board appreciates his significant contribution to the production of six volumes of the *Science Indicators* series during his tenure as Head of the Science Indicators Unit from 1975 to 1985.

The Board is also grateful to the special contributors and to those who reviewed the draft chapters of *Science & Engineering Indicators—1987*, all of whom are listed in Appendix II. Thanks are also due to the staff of the NSF Printing Office and to the editors at Evaluation Technologies, Incorporated for their assistance in the production of this complex document.

[1]From August 1986.
[2]Through July 1986.

# overview
# of
# U.S. Science and Technology

# Overview of U.S. Science and Technology

## SYNOPSIS

By all conventional standards, U.S. research and development (R&D) has enjoyed vigorous growth in recent years. The two major sources of R&D funds—the Federal Government and industry—have been driven by the twin concerns of national security and economic competitiveness to maintain a fast pace of R&D investment.

In 1986 the U.S. research and development enterprise entered its 10th year of uninterrupted real expansion with a healthy 5.9 percent constant-dollar increase over 1985. The basic research component of R&D also continued to expand, although at a slightly lower rate (5.4 percent between 1985 and 1986). Similar continuing growth patterns are evident in the employment of science and engineering (S/E) personnel in the economy, and in R&D as a percentage of gross national product (GNP). S/E enrollments and degrees have also shown small upward trends although, as discussed below, this may be the result of the flow of foreign citizens into S/E fields, especially at the graduate level.

In several areas relevant to science and technology (S/T), the U.S. can be seen as in a "holding pattern" over the past decade. For example, in the area of technological innovation, the number of patents granted to U.S. organizations or individuals has fluctuated within a fairly narrow range over the period. The U.S. has also continued to maintain both its share of world international trade in high-technology goods and world scientific publications in all fields with only a slight drop in these over the decade.

Matters for concern appear at both the input and output ends of the S/T spectrum—the condition of precollege science and mathematics education, and the ability of U.S. corporations to compete in world markets for high-technology goods.

There is no evidence of an upturn in the low performance levels of U.S. schoolchildren on science and mathematics achievement tests, nor in their continuing relatively poor performance on such tests in comparison with some other industrial countries. U.S. State and local school jurisdictions have recently been investing significant resources in this problem area, but it is apparently too soon to see any results.

Compounding the "input issue," are the demographics of the 1990's. The shrinking of the college-age population suggests difficulties in maintaining an adequate flow of new science and engineering personnel unless young people—especially minorities and women—can be induced to increase their participation rates in college science and engineering programs.

At the output end, in 1986 the U.S. balance of trade in high-technology goods became—for the first time—a negative, thus intensifying the search for measures to improve U.S. international economic competitiveness.

The following displays summarize the major findings delineated in the various chapters of *Science & Engineering Indicators—1987*. Each data display is referenced to the discussion in the appropriate chapter.

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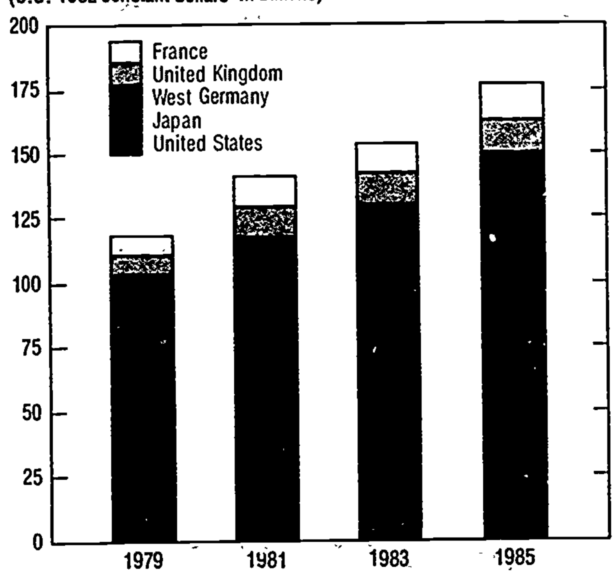
## R&D INVESTMENTS IN A WORLD CONTEXT

In the world context, the U.S. makes by far the largest investments in R&D of any Western country. (See figure O-1.) The U.S. spends more on R&D than the next four largest countries combined. Despite the difference in absolute size, the U.S. invests approximately the same proportion of its GNP in R&D as do the other major noncommunist industrialized countries. The display also shows that in recent years, the R&D growth rates of Japan and West Germany have been rising faster than that of the U.S., enabling these countries to match U.S. R&D spending as a percent of GNP. (See figure O-2.)

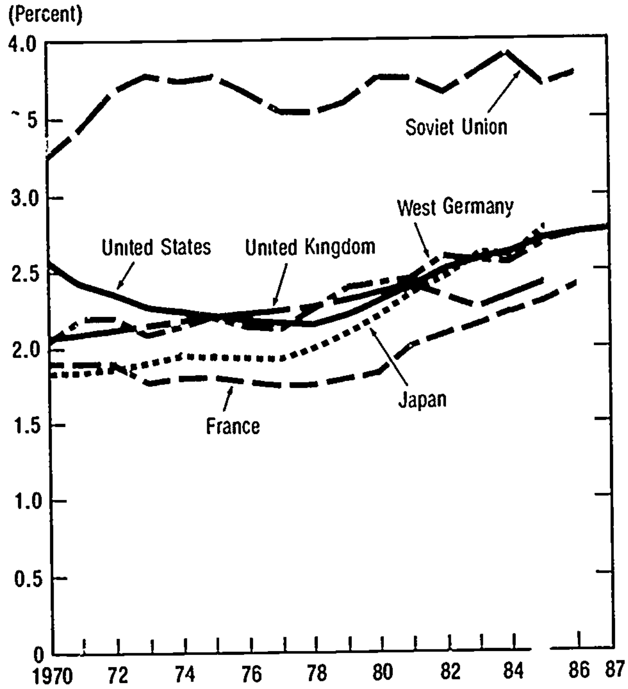
The data in figure O-2 show that in recent years other nations have caught up with the U.S. in R&D investments. However, the nature of the investments must also be taken into account. If only nondefense R&D is considered, West Germany and Japan have been ahead of the U.S. for 15 years, and their rate of civilian R&D investment as a percent of GNP has been rising faster than that of the U.S. for the past 5 years. (See figure O-3.)

Figure O-1.
**Expenditures on research and development in selected countries**



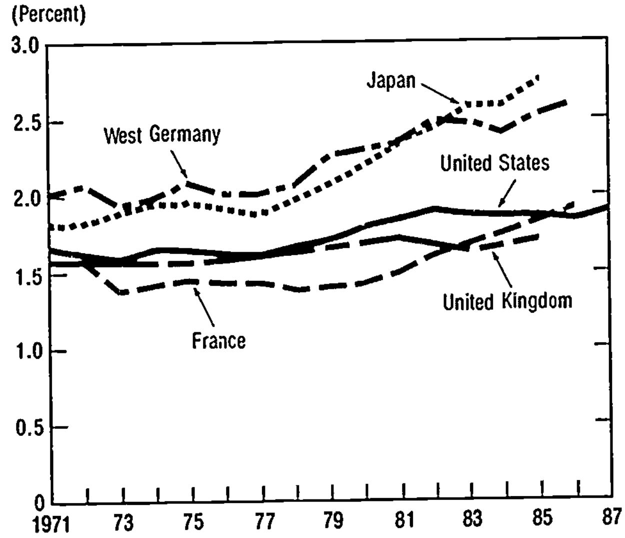

¹Foreign currency data are converted into U.S dollars using current purchasing power parities. The data are then converted to 1982 dollars using the U.S. GNP deflator.
See appendix table 4-1 and p. 77. Science & Engineering Indicators — 1987

Figure O-2.
**R&D expenditures as a percent of GNP, by country**




See appendix table 4-2 and p. 77. Science & Engineering Indicators — 1987

Figure O-3.
**Non-defense R&D expenditures as a percent of GNP, by country**




See appendix table 4-3 and p. 77. Science & Engineering Indicators — 1987

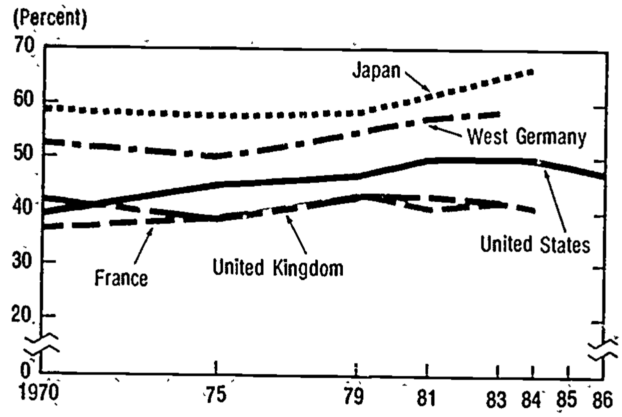
As the share of national R&D effort a country devotes to defense-related activities increases, the share of resources it devotes to business-related activities decreases. Figure O-4 shows a similar pattern to figure O-3—in West Germany and Japan, a significantly higher proportion of national R&D investments derive from business sources.

Continued growth is observed in U.S. R&D expenditures, both in constant dollars (figure O-5) and as a percentage of GNP—2.76 percent in 1986, the highest level since 1968.

In recent years, development funds have grown at a faster rate than has support for basic or applied research.

A breakdown of Federal defense and nondefense R&D by character of work highlights the defense development buildup, and also the increasing growth of basic research in Federal nondefense R&D. (See figure O-6.)

Figure O-4:
**Percent of total national R&D expenditures derived from business sources**




See appendix table 4-1 and p. 77.

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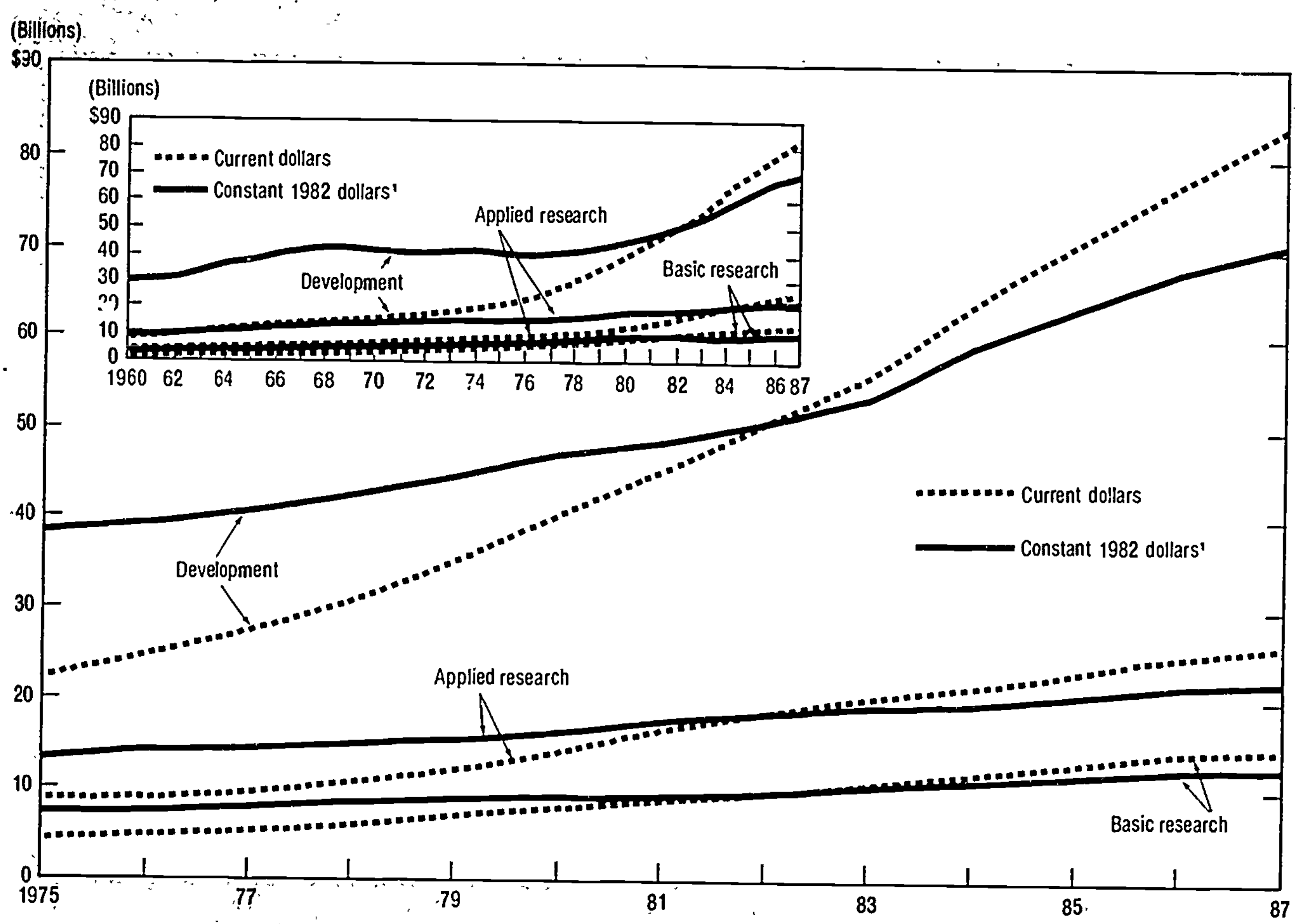
Figure O-5:
**National R&D expenditures by character of work**




¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: Estimates are shown for 1985, 1986 and 1987.

See appendix table 4-6 and p. 77.

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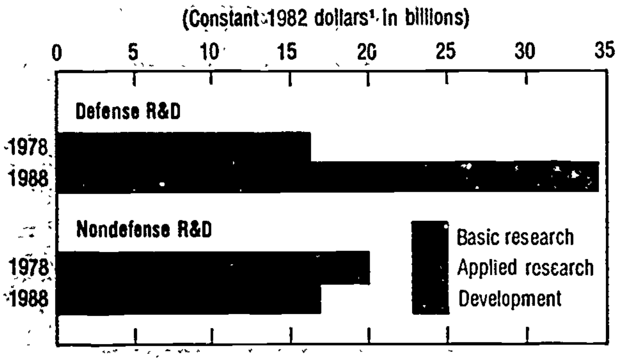
Figure O-6.
**Relative changes in Federal obligations for defense and nondefense R&D by character of work in constant 1982 dollars[1]**



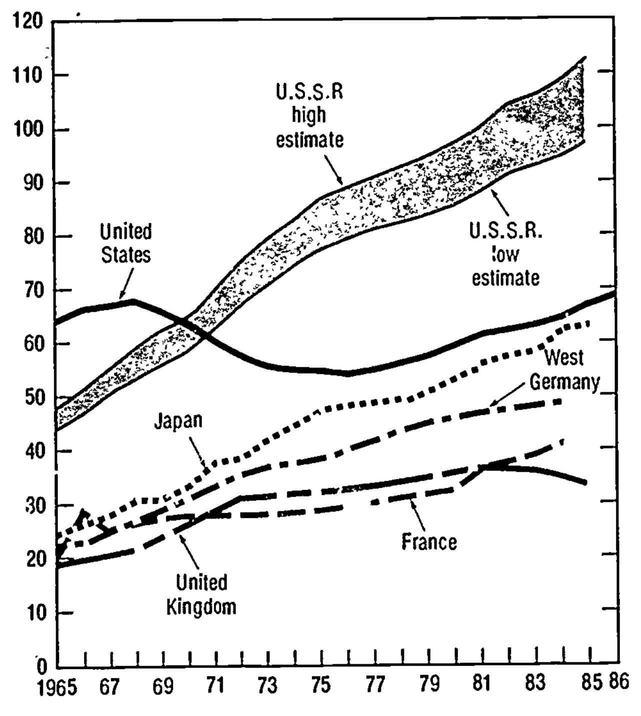

[1]GNP implicit price deflators used to convert current dollars to constant 1982 dollars.
See appendix table 4-37 and p. 77. Science & Engineering Indicators — 1987

## International Comparisons

Compared with other advanced industrial countries, the U.S. proportion of scientists and engineers in the labor force who are engaged in R&D has been growing faster than Western European countries, but slower than Japan. (See figure O-7.) Because of the great differences between the Soviet system and the market economies, comparisons with Soviet data require caution.

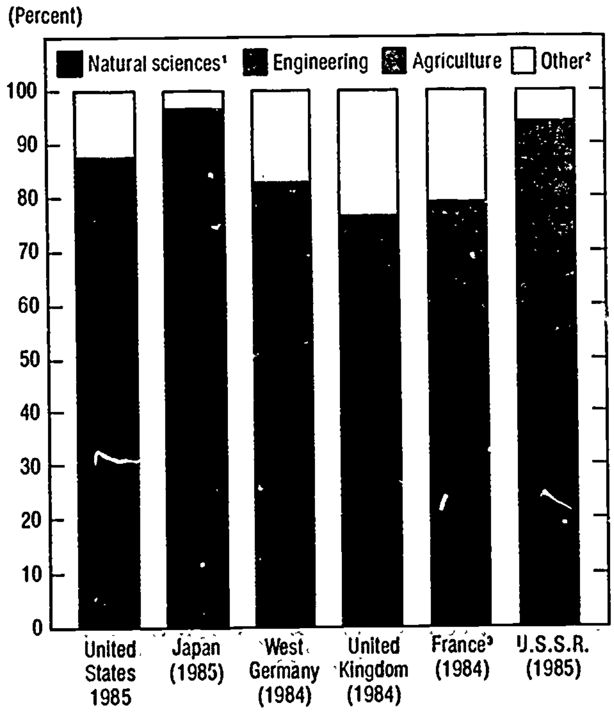
Advanced industrial countries vary considerably in the proportion of all first academic degrees which are in S/E fields, as well as in the relative proportions of natural scientists and engineers. (See figure O-8.) Soviet and Japanese degrees are heavily weighted towards engineers, while in the United Kingdom natural science degrees outnumber engineering degrees.

Figure O-7.
**Scientists and engineers engaged in R&D per 10,000 labor force population**




See appendix table 3-17 and p. 71. Science & Engineering Indicators — 1987

Figure O-8.
**First university degrees by field and country**




[1]Includes physical sciences, biological sciences, and mathematics.
[2]Includes social sciences.
[3]Degrees for France are maitrise degrees, plus engineering degrees. French agricultural sciences are included in natural science.
See appendix table 3-23 and p. 71. Science & Engineering Indicators — 1987

## S/E Employment in the U.S.

The employment of scientists and engineers continues to grow as a percentage of the total U.S. labor force. (See table O-1.)

Scientists and engineers have grown more rapidly than several other aspects of the economy—such as total employment and GNP. (See figure O-9.)

There are about 10 percent more employed engineers than scientists in the S/E labor force; S/E distribution by field is shown in figure O-10.

**Table O-1. Employed scientists and engineers as a percent of total U.S. employment**

| Year | Percent |
|---|---|
| 1976 | 2.4 |
| 1978 | 2.5 |
| 1980 | 2.6 |
| 1982 | 2.9 |
| 1984 | 3.3 |
| 1986 | 3.6 |

SOURCES: Based on National Science Foundation, *U.S. Scientists and Engineers: 1984; Economic Report of the President, 1987*, pp. 282; National Science Foundation, Division of Science Resources Studies, unpublished data.

See appendix table 3-2 and p. 53.

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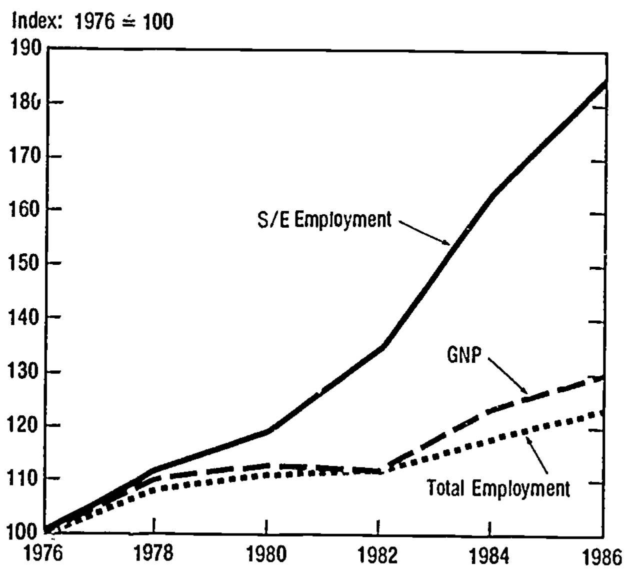
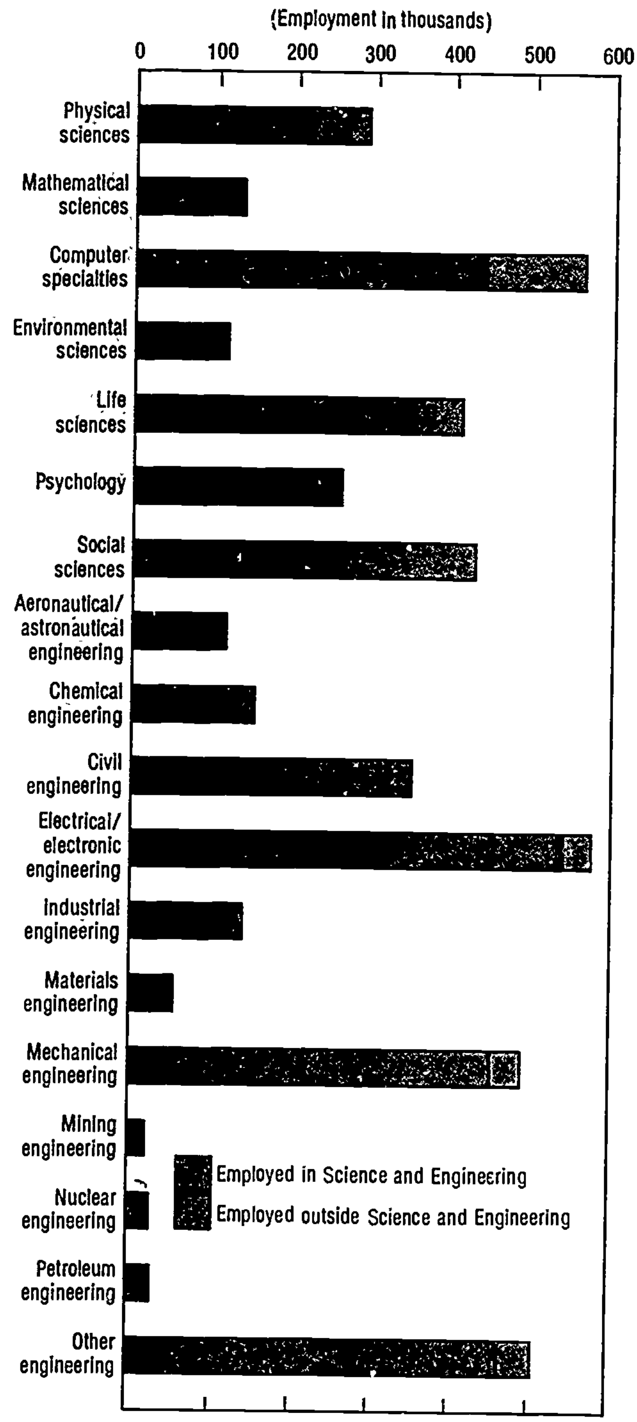
Figure O-9.
**Relative growth of selected economic indicators**




See appendix table 3-3 and page 53. Science & Engineering Indicators — 1987

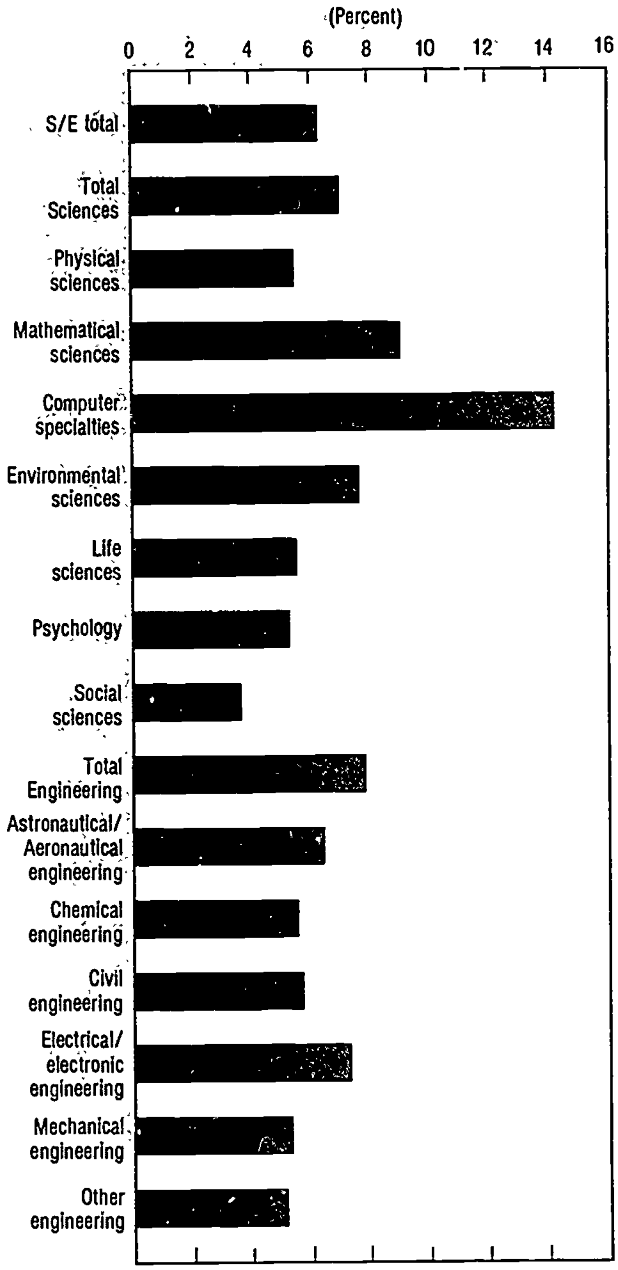
Figure O-10.
**Scientists and engineers employed in S/E jobs and in non-S/E jobs, by field: 1986**




See appendix table 3-1 and p. 53. Science & Engineering Indicators — 1987

S/E relative growth rates are shown in figure O-11. The most remarkable recent trend has been the rapid growth of computer specialists at all levels of education.

Figure O-11.
**Employed scientists and engineers, average annual growth, by field: 1976 to 1986**




See appendix table 3-1 and pp. 53, 54.
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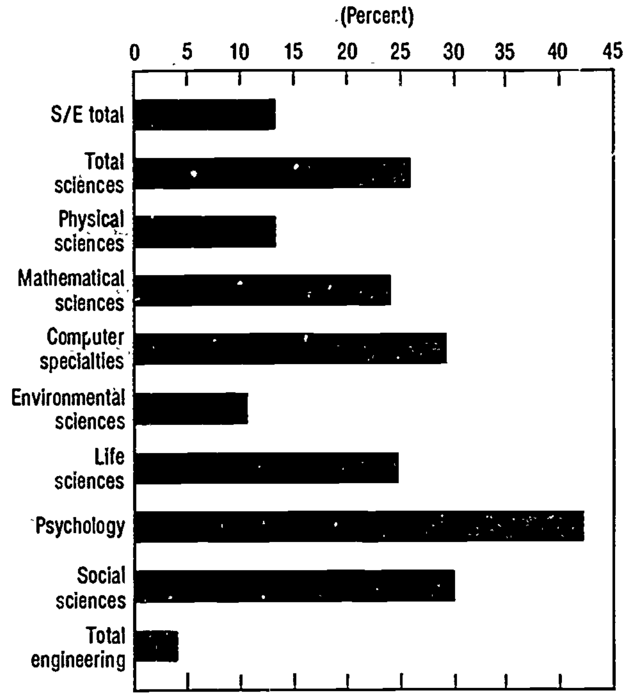
## Women and Minorities in S/E

Employment of women and minorities has increased rapidly, but they continue to be underrepresented in science and engineering. Women constituted less than 4 percent of all engineers and nearly 25 percent of employed scientists. They were more heavily represented in some fields than others. (See figure O-12.)

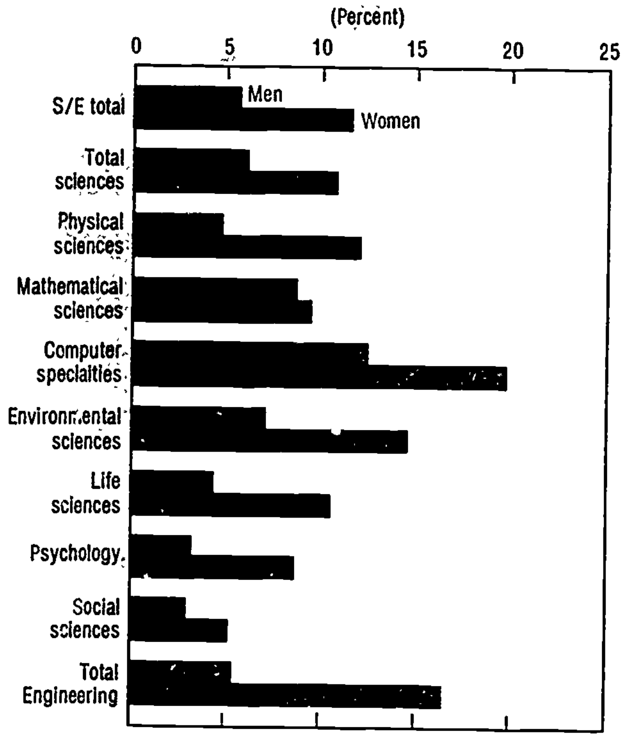
Figure O-12.
**Women as percent of total employed scientists and engineers in S/E fields: 1986**




See appendix table 3-1 and p. 62. Science & Engineering Indicators — 1987

The S/E fields enjoying the most rapid increases in employment of women are shown in figure O-13. Again, computer specialists show remarkable growth.

Figure O-13.
**Average annual growth rates of employed scientists and engineers by S/E field and sex: 1976-1986**

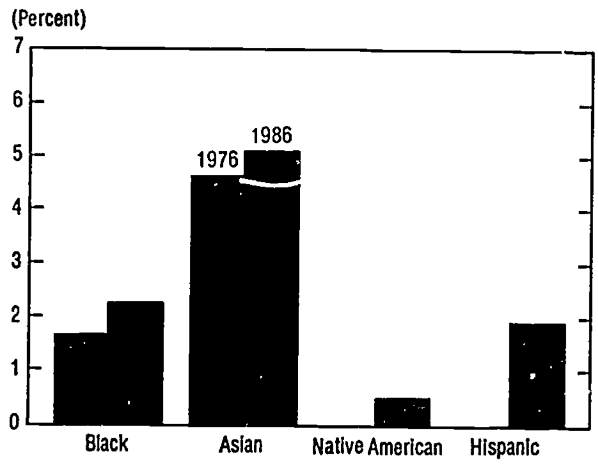



See appendix table 3-1 and p. 62. Science & Engineering Indicators — 1987

Blacks and Hispanics remain underrepresented in S/E jobs, although blacks made significant gains over the decade. (See figure O-14.) Recent data on enrollment of U.S. blacks and Hispanics in graduate S/E degree programs show level or declining participation (see chapter 2, "Higher Education for Scientists and Engineers," p. 43), suggesting slow future growth in minority S/E employment.

Asian-Americans have increased their share of S/E jobs from 5 percent to 6 percent; this is far greater than their distribution in the population.

Figure O-14.
**Employment of minority scientists and engineers as a percentage of total employment of scientists and engineers**




See appendix tables 3-21 and pp. 63, 91. Science & Engineering Indicators — 1987

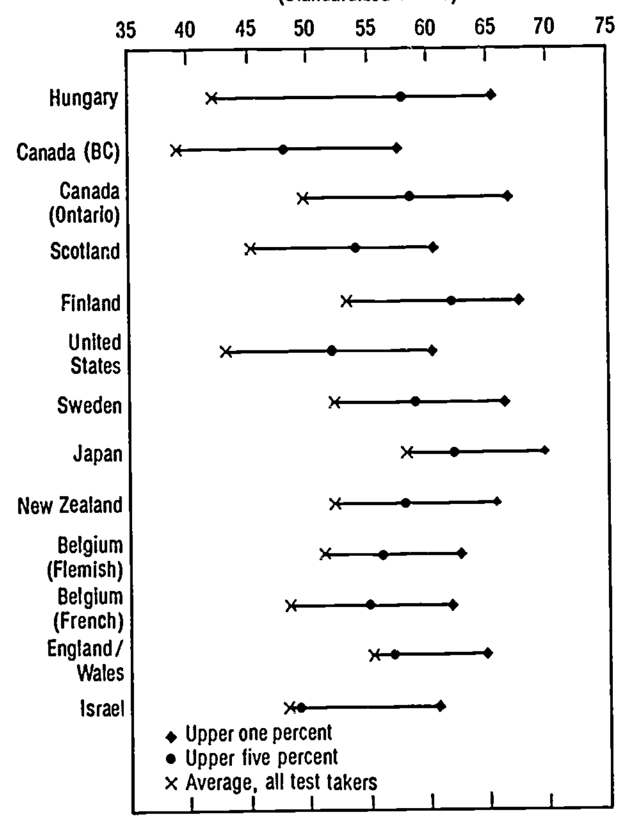
## Precollege Education

In a series of international comparative studies, U.S. college preparatory mathematics students scored lower on achievement tests than did their counterparts in most of the countries studied. (See figure O-15.)

Since 1969, the National Assessment of Educational Progress studies have tracked the achievement of national samples of 9-, 13-, and 17-year-olds on mathematics and science tests. Between 1969 and 1977 performance on these tests declined among all age groups, but since 1977 there have been no statistically significant changes in the scores for the whole population of children.

Figure O-15.

**Achievement in functions and calculus of the top 1% and 5% of 12th grade students, by country: 1981/82**



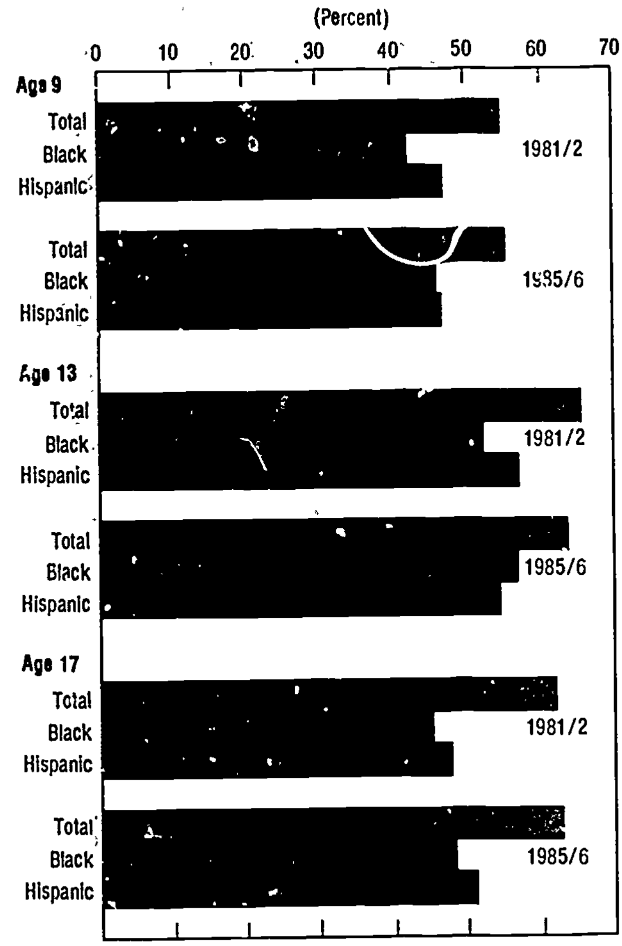

Note: Countries are arranged in decreasing order descending from top to bottom of the proportion of students enrolled in advanced mathematics programs

See appendix table 1-6 and p. 24. Science & Engineering Indicators — 1987

Recently, however, some interesting shifts have occurred among specific groups. Between 1981 and 1986, black children of all ages registered significant test score gains in both science and mathematics. In the 1985/6 test, black 13-year-olds outscored Hispanic 13-year-olds for the first time in both subject matters. (See figures O-16 and O-17.)

Figure O-16.

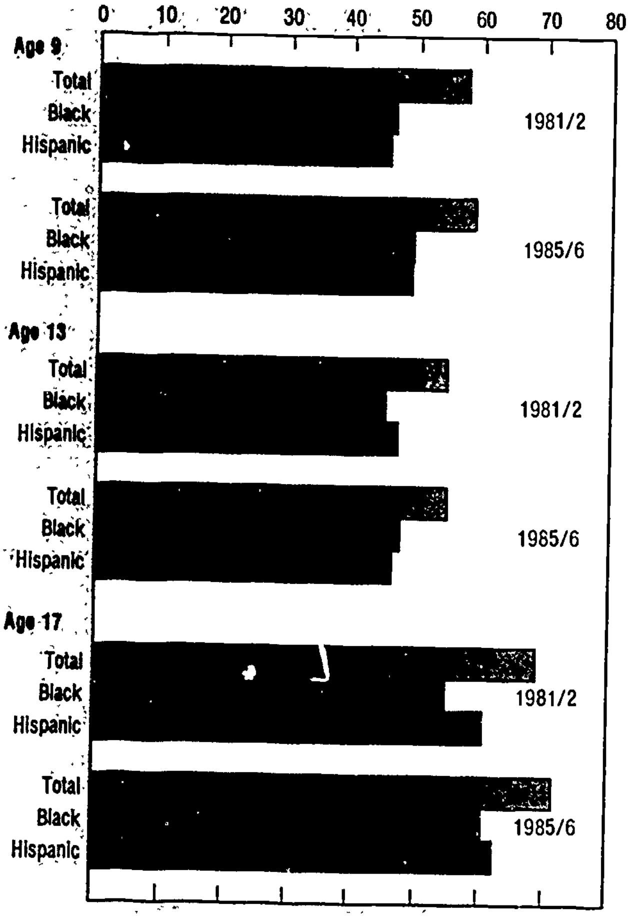
**Achievement scores in mathematics, by age, race, and year**




See appendix table 1-1 and p. 21. Science & Engineering Indicators — 1987

Further, 17-year-olds from all ethnic groups showed small overall gains in both science and mathematics scores. The improvements in mathematics are believed to be related to increased enrollments in intermediate and advanced mathematics courses.

Figure 0-17.
**Achievement scores in science, by age, race, and year**




See appendix table 1-2 and p. 21. Science & Engineering Indicators — 1987

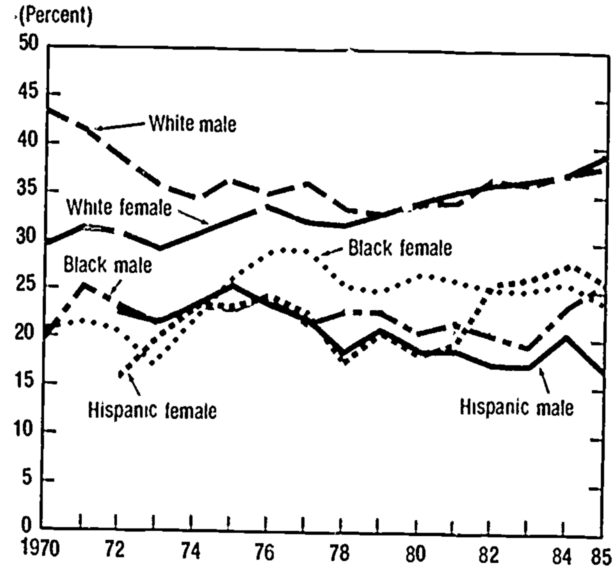
## Higher Education

Increases of 5 to 6 percentage points in the college-going rates for U.S. 18- to 21-year-olds are observable over the past 5 years. These increases in the college-going rates of some groups—especially women—have kept total enrollments on the undergraduate level sufficiently high to compensate for the declining size of the 18-year-old population which began in 1979. (See figure O-18.)

The past decade's rapid growth of engineering and computer science students has ended. From 1982-86, there was a dramatic decline in computer science as a freshman major and a smaller decline in engineering. (See figure O-19.)

Parallel declines are seen in freshman choices of these areas as probable future occupations.

Figure 0-18.
**College-going rates of 18-21 year olds, by selected race and gender**

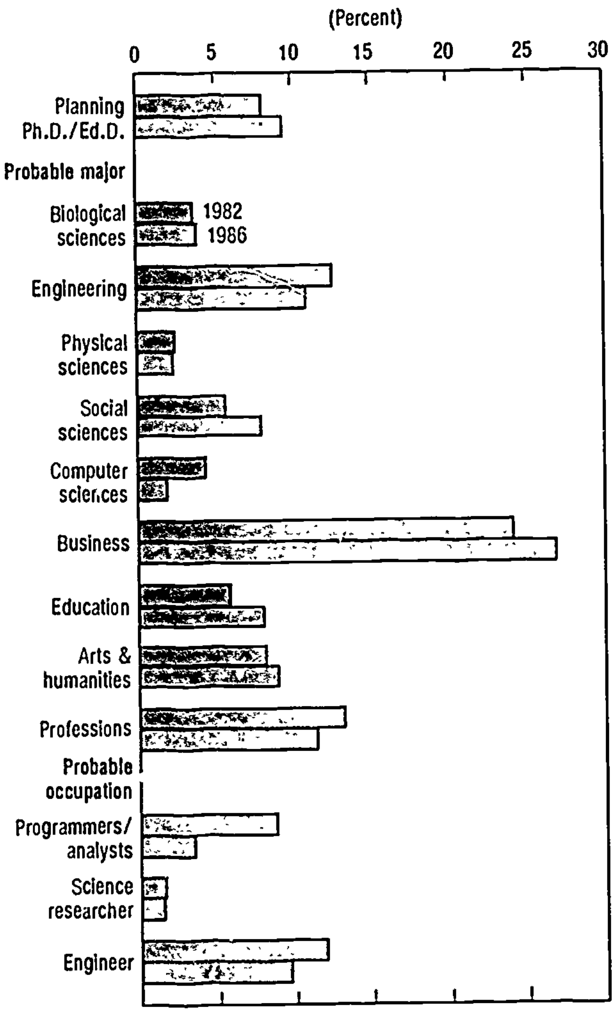



See appendix table 2-1 and pp. 41 and 44. Science & Engineering Indicators — 1987

S/E degrees at all levels increased from 1982-85: bachelor's degrees increased by 6 percent, master's by 4 percent, and doctorates by nearly 8 percent. (See table O-2.)

Engineering, mathematics, and computer science contributed the greatest increases at the bachelor's and master's degree levels, with other sciences registering either declines or no growth. Doctoral degrees increased in all fields, led by engineering and computer science.

Figure O-19.
**Freshmen plans: 1982 and 1986**




See table 2-2 on p. 42 Science & Engineering Indicators — 1987

**Table O-2. Science and engineering degrees, by level and field**

| Degree level and field | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|
| Total S/E bachelor's .. | 302,118 | 307,225 | 314,666 | 321,739 | NA |
| Physical sciences . | 24,372 | 23,497 | 23,759 | 23,847 | NA |
| Engineering ...... | 67,791 | 72,954 | 76,531 | 77,871 | NA |
| Mathematics ...... | 11,708 | 12,557 | 13,342 | 15,267 | NA |
| Computer sciences | 20,431 | 24,678 | 32,435 | 39,121 | NA |
| Life sciences ..... | 65,041 | 63,237 | 59,613 | 57,812 | NA |
| Psychology ....... | 41,539 | 40,825 | 40,375 | 40,237 | NA |
| Social sciences ... | 71,236 | 69,477 | 68,611 | 67,574 | NA |
| Total S/E master's ... | 57,025 | 58,868 | 59,569 | 61,278 | NA |
| Physical sciences . | 5,526 | 5,288 | 5,568 | 5,802 | NA |
| Engineering ...... | 18,594 | 19,721 | 20,352 | 21,206 | NA |
| Mathematics ...... | 2,731 | 2,839 | 2,749 | 2,888 | NA |
| Computer sciences | 4,935 | 5,321 | 6,190 | 7,101 | NA |
| Life sciences ..... | 9,824 | 9,720 | 9,330 | 8,757 | NA |
| Psychology ....... | 7,849 | 8,439 | 8,073 | 8,481 | NA |
| Social sciences ... | 7,566 | 7,540 | 7,307 | 7,043 | NA |
| Total S/E doctor's .. . | 17,626 | 17,932 | 18,069 | 18,261 | 18,792 |
| Physical sciences . | 3,351 | 3,439 | 3,459 | 3,534 | 3,679 |
| Engineering ...... | 2,646 | 2,781 | 2,913 | 3,167 | 3,376 |
| Mathematics ...... | 720 | 701 | 698 | 688 | 730 |
| Computer sciences | 220 | 286 | 295 | 311 | 399 |
| Life sciences ..... | 4,841 | 4,749 | 4,869 | 4,882 | 4,790 |
| Psychology ....... | 3,158 | 3,309 | 3,230 | 3,072 | 3,071 |
| Social sciences ... | 2,690 | 2,666 | 2,608 | 2,608 | 2,747 |

SOURCE: National Science Foundation, Science & Engineering Education Sector Studies Group, unpublished data

See figure 2-3, appendix tables 2-9 and 2-10 and pp. 44-45.

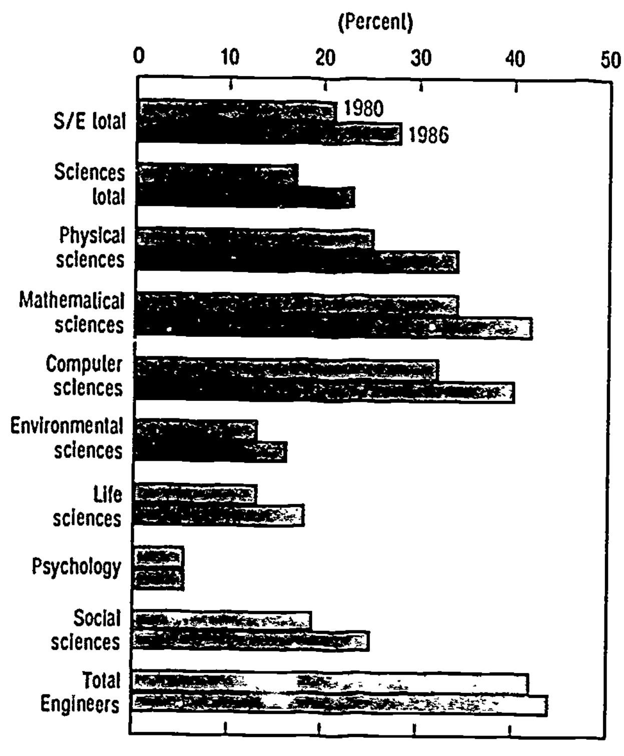
Science & Engineering Indicators—1987

Over the past decade, foreign students have increased significantly in all S/E fields as a proportion of all graduate students enrolled in U.S. doctoral-granting institutions. (See figure O-20.) The trend is strongest in the mathematical, physical, and computer sciences.

Graduate degrees granted to foreign citizens have also increased, in 1984, for example, 52 percent of all U.S. engineering Ph.D.'s were awarded to foreign citizens.

Figure O-20.

**Foreign students as a percent of full-time graduate enrollment, by field of study**




Note: Doctorate-granting institutions only

See appendix table 2-4 and p. 44    Science & Engineering Indicators – 1987

## KNOWLEDGE CREATION AND APPLICATION

The relative strength of U.S. basic and applied research is indicated by the share of articles written by U.S. authors in the world's leading S/E journals. Over the past decade, the U.S. has more or less maintained this share, with some decreases in biology and mathematics. (See table O-3.)

The data in figure O-21 suggest the increasing relevance of foreign scientific work to U.S. science and engineering research. Between 1974 and 1984, there were significant increases across all S/E fields in the percentage of all references in U.S.-authored articles to non-U.S. articles.

Since 1976, U.S. inventors have been granted around 40,000 patents a year. U.S. patents granted to foreign inventors, however, increased by one-third during the same period. (See figure O-22.) Japanese inventors were by far the most active in increasing their U.S. patenting.

**Table O-3. U.S. share of world scientific and technical articles[1] by field**

| Field[2] | 1973 | 1981[3] | 1984[3] |
|---|---|---|---|
| | Percent | | |
| All fields | 38 | 35 | 35 |
| Clinical medicine | 43 | 40 | 41 |
| Biomedicine | 39 | 39 | 39 |
| Biology | 46 | 38 | 37 |
| Chemistry | 23 | 20 | 21 |
| Physics | 33 | 28 | 27 |
| Earth and space sciences | 47 | 42 | 41 |
| Engineering and technology | 42 | 41 | 40 |
| Mathematics | 48 | 38 | 37 |

[1] Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

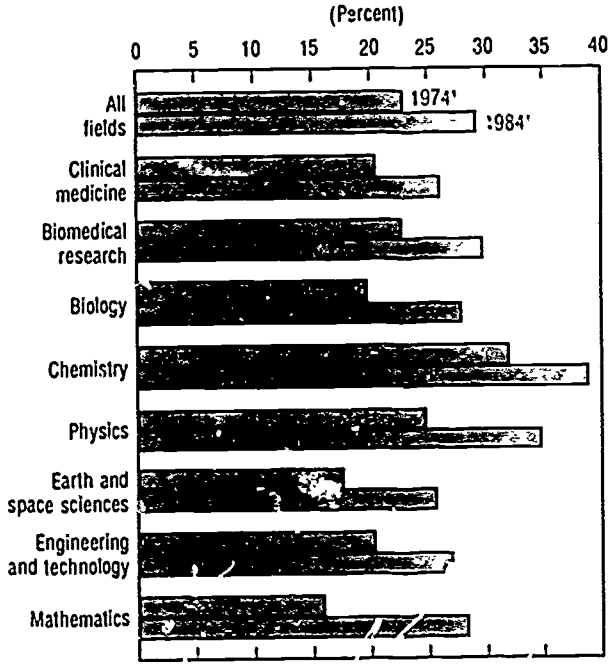
[2] See appendix table 5-27 for the subfields included in these fields.

[3] Uses over 3,500 of the influential journals carried on the 1981 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

See appendix table 5-26 and p. 99.

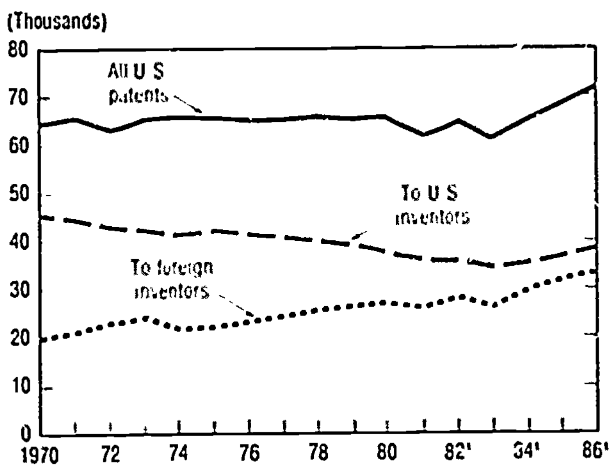
Science & Engineering Indicators—1987

Figure 0-21.
**U.S. references to foreign articles, as a percent of all references in U.S. authored articles**




¹Year of publication of articles in which references are found
See appendix table 5-28 and p. 99 Science & Engineering Indicators — 1987

Figure 0-22.
**U.S. patents granted, by nationality of inventor and date of application**



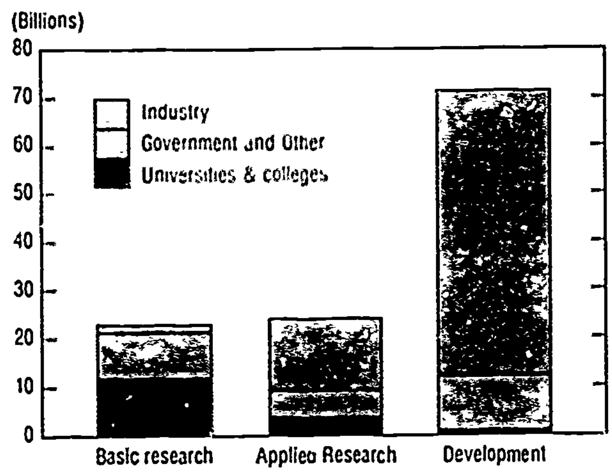

¹Estimates are shown for 1982-86
See appendix table 6-8 and p. 107 Science & Engineering Indicators — 1987

## RESEARCH

The distribution of performance of basic and applied research and development among the institutional sectors in the U.S. varies greatly. (See figure O-23.) Measured in dollars, the academic sector performs slightly less than one-half of all basic research, about 10 percent of all applied research, and less than 1 percent of development. Industry is the mirror image of academia, performing four-fifths of all development work, more than three fifths of applied research, and about one-fifth of all basic research. The sector encompassing the Federal Government (including Federally funded R&D centers) and other performers accounted for about one-third of all basic research, a little more than one-third of all applied research, and about one-sixth of all development activities.

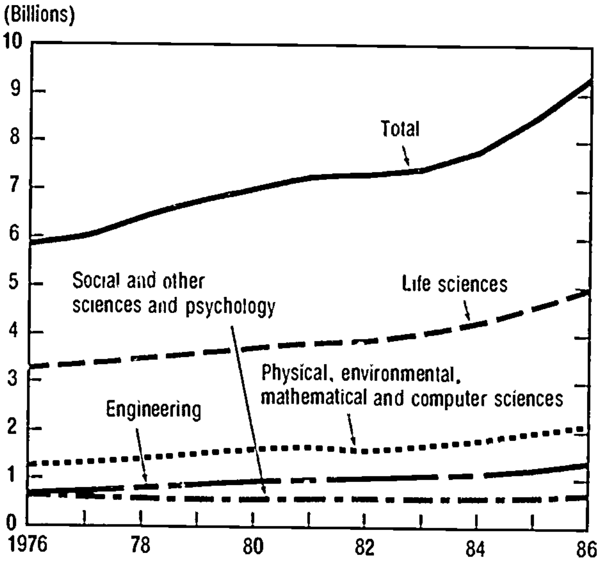
Academic R&D has grown significantly over the past decade—55 percent between 1976 and 1986 in constant dollars. (See figure O-24.) While the overall pattern of academic research has not changed markedly, there have been some significant shifts among fields. Engineering research has increased its share of the total by about 3 percent, and the broad group of physical sciences has claimed an additional 2 percent over the decade. The life sciences lost a 1-percent share, while the biggest losses of total share were incurred by the social and psychological sciences and other sciences, which dropped by 4 percent.

Figure 0-23.
**Basic and applied research and development, by sector: 1985**




See appendix table 4-7 and p. 77 Science & Engineering Indicators — 1987

Figure 0-24.
**Expenditures for academic research and development, by field**




See appendix table 4-19 and p. 79 — Science & Engineering Indicators — 1987

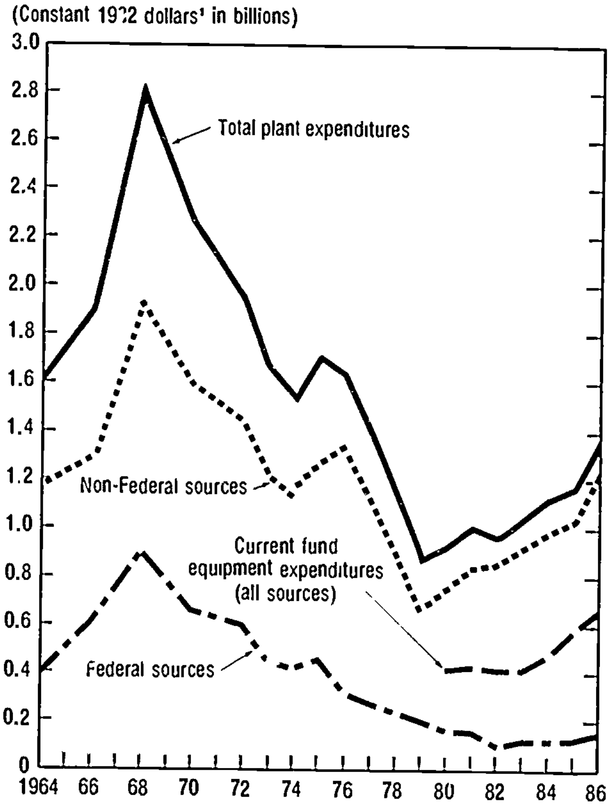
The Nation is currently experiencing an upsurge of capital spending for academic science and engineering, although the overall constant-dollar expenditures in recent years remain less than one-half their 1968 peak levels. (See figure O-25.)

Federal sources have continued to decline as a percentage of total capital expenditures for academic S/E, providing 11 percent of the total in 1985—their lowest percentage in more than 2 decades.

According to a 1986 survey of doctorate-granting research universities, the bulk of support for new S/E capital construction in progress is coming from non-Federal sources such as State Governments (40 percent), funds from tax-exempt bonds (30 percent), and private donations or endowments (14 percent).

Current fund expenditures for research equipment at universities and colleges increased by 80 percent between 1980 and 1985. (See figure O-25.) Funds from all sources grew at approximately the same rate, but—unlike the pattern for facilities spending—nearly two-thirds of the equipment funds came from Federal Government agencies.

Figure 0-25.
**Plant and equipment expenditures in academic S/E, by source of funds**



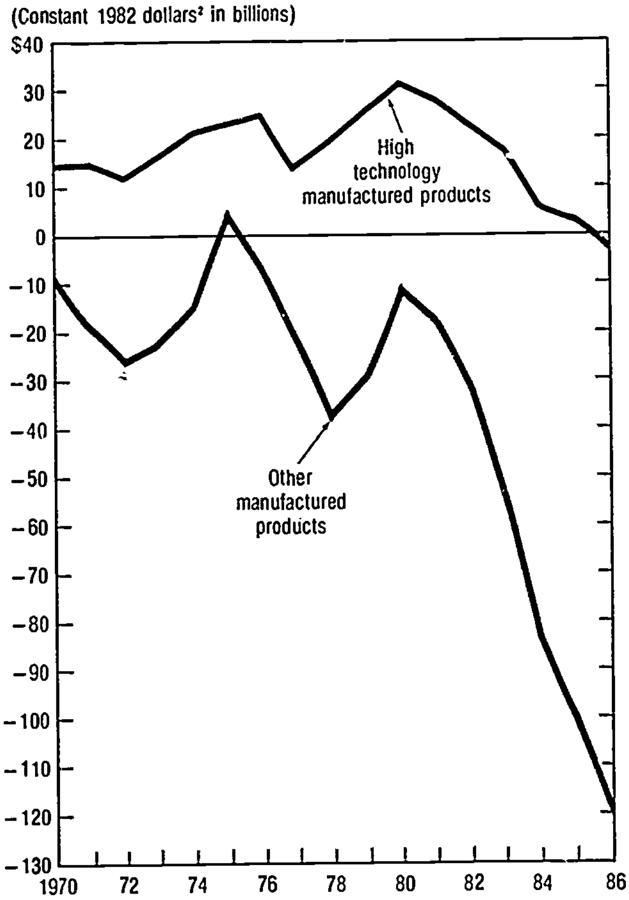

[1]GNP implicit price deflators used to convert dollars to constant 1982 dollars
See appendix table 4-22 and pp. 80, 81 — Science & Engineering Indicators — 1987

## U.S. High-Technology Performance in International Markets

Figure O-26 depicts the trend in the U.S. trade balance in high-technology and other manufactured product groups. U.S. trade in high-technology goods has maintained a positive—though declining—trade balance during the past 15 years. In 1986, for the first time, the U.S. balance of trade in high-technology goods dipped into the negative. Other manufactured goods have had a negative and still declining balance of trade.

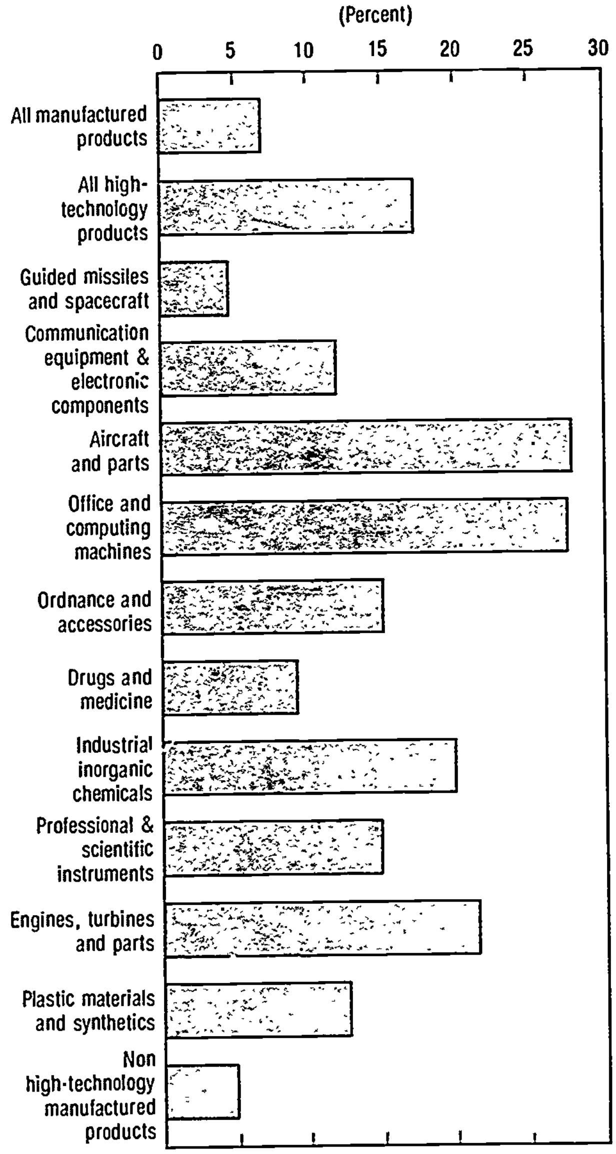
The importance of foreign markets to a number of U.S. high-technology industries is shown in figure O-27. In several product fields, more than one-quarter of total shipments is exported.

Figure 0-26.
**U.S. trade balance[1] in high-technology and other manufactured product groups**




[1]Exports less imports.
[2]GNP implicit price deflators used to convert current dollars to constant 1982 dollars
See appendix table 7-1 and p. 124 Science & Engineering Indicators — 1987

Figure 0-27.
**U.S. exports as a percent of shipments, high-technology products, 1985**




See appendix table 7-2 and p 124
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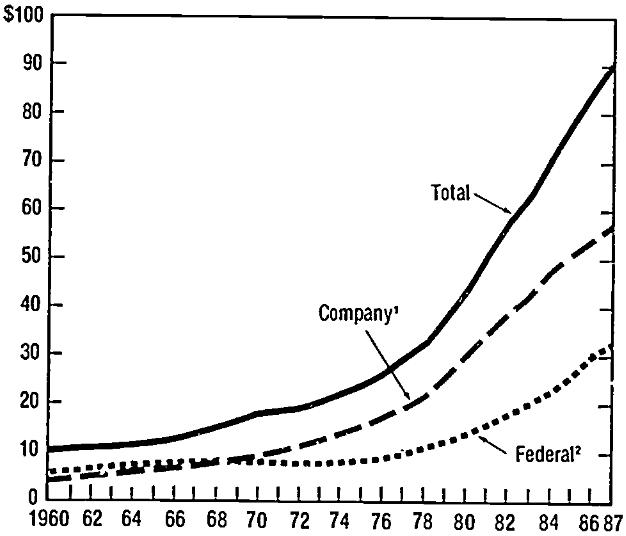
S/T in U.S. Industry

In 1986, U.S. industry supplied 50 percent of the country's R&D funds, and performed 73 percent of the total R&D. As figure O-28 shows, industry's funding of its own R&D activities has been rising at a faster rate than Federal funding for industrial R&D for almost a decade. As figure O-29 dramatically illustrates, most of this increase has been occurring in the high-technology manufacturing industries.

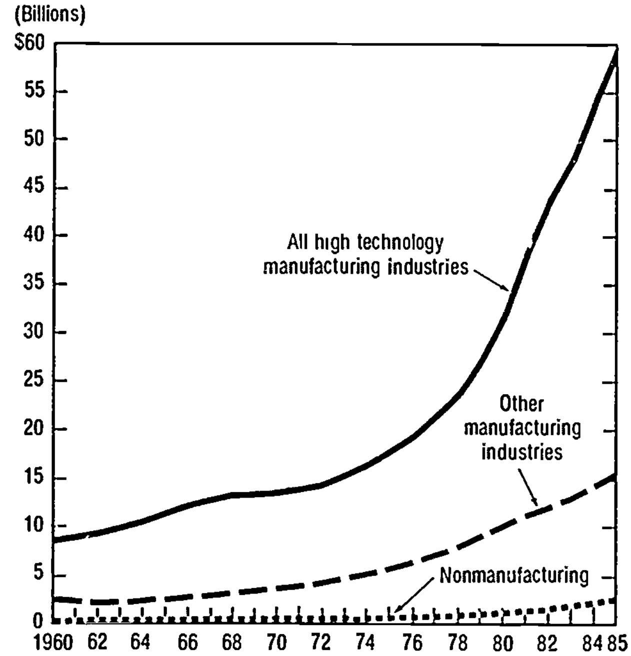
In the U.S., large corporations perform the bulk of industrial R&D, and manufacture most of the high-technology products. Small high-technology businesses, however, introduce a disproportionate amount of new high-technology products, especially in relation to their R&D expenditures. (See figure O-30.)

Figure O-28.
**Expenditures for industrial R&D by source of funds**



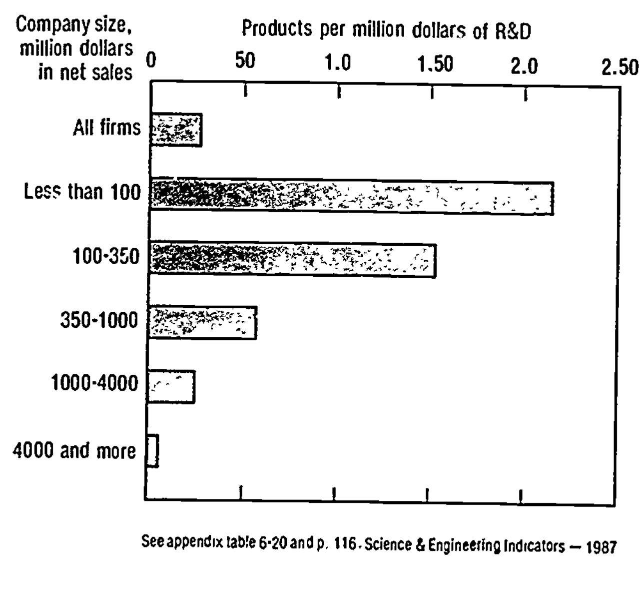

[1]Includes all sources other than the Federal Government.
[2]Includes Federally Funded Research and Development Centers administered by industry.
Note: Preliminary data are shown for 1985 and estimates for 1986 and 1987.
See appendix table 6-2 and p. 104. Science & Engineering Indicators — 1987

Figure O-29.
**R&D expenditures, by industry group**




Note: Data include Federally Funded Research and Development Centers administered by industry.
See appendix table 6-3 and p. 105. Science & Engineering Indicators — 1987

Figure O-30.
**New products introduced in 1985, per million dollars of R&D**

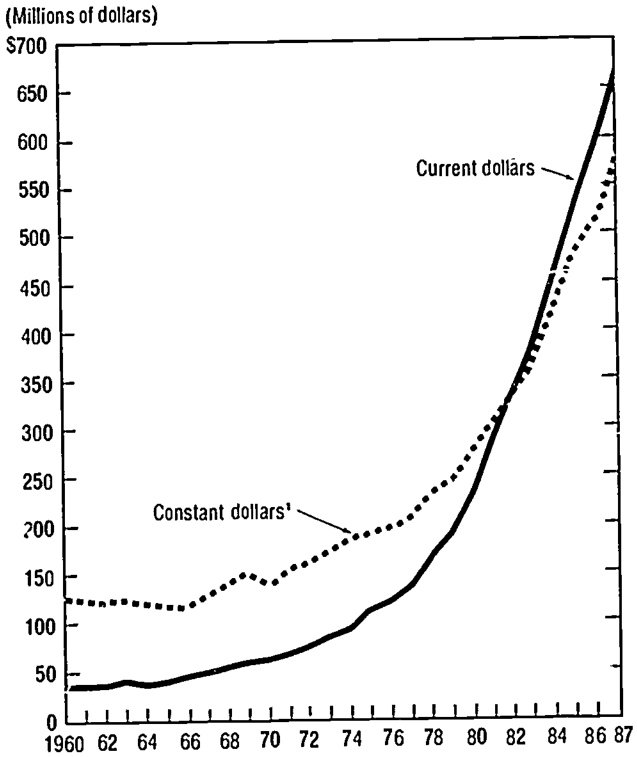



See appendix table 6-20 and p. 116. Science & Engineering Indicators — 1987

One of the most striking changes in R&D funding patterns in the past decade has been industry's support of university research. Figure O-31 shows that this trend is continuing apace, although it only just exceeds 5 percent of university R&D.

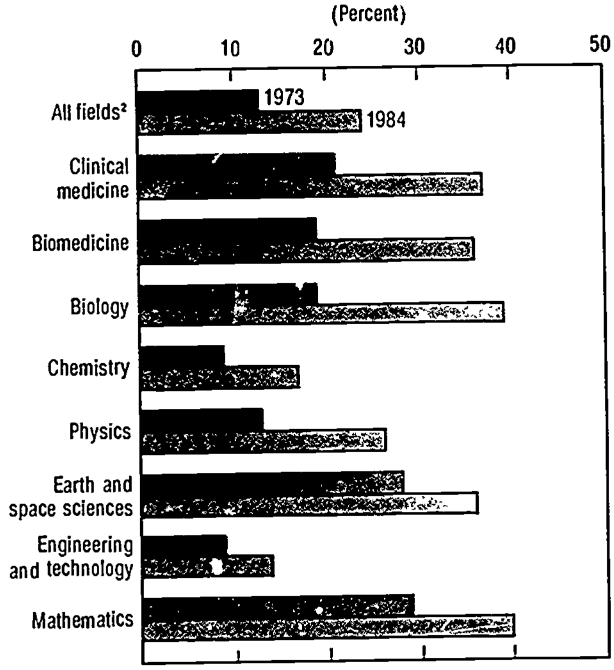
The increasing intensity of the university-industry research relationship is reflected in the increases in coauthorship of scientific articles by industry and university scientists over the past decade. (See figure O-32.)

Figure O-31.
**Industry expenditures for R&D in colleges and universities**




[1]GNP implicit price deflators used to convert current dollars to constant 1982 dollars
Note. Estimates are shown for 1986 and 1987.
See appendix table 4-10 and p. 78. Science & Engineering Indicators — 1987

Figure O-32.
**Portion of all journal publications[1] written with industry participation that are co-authored with universities**




[1]Includes the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.
[2]See appendix table 5-27 for a description of the subfields included in these fields.
See appendix table 5-15 and p. 96. Science & Engineering Indicators — 1987

## PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

In 1981, the first major international comparative study of public attitudes towards science and technology was conducted. The study's results, which have recently become available, show that by a significant margin, the U.S. public held the most optimistic view of the long-run contributions of science to society. (See figure O-33.)

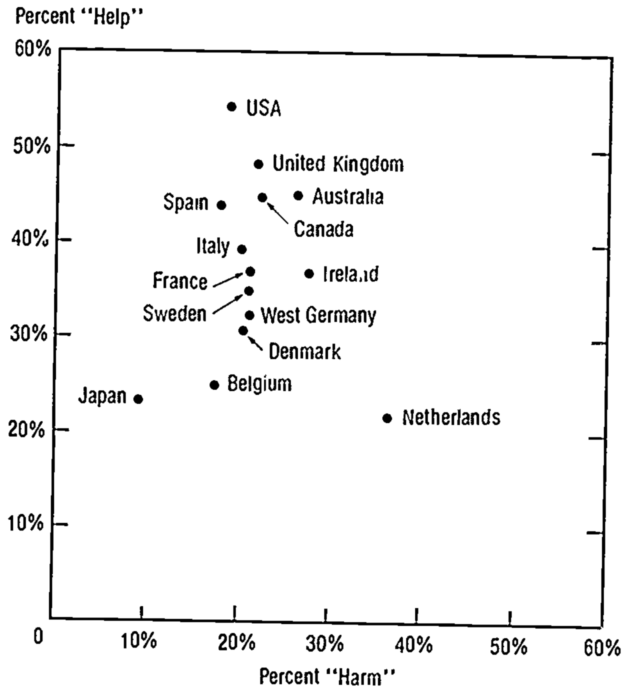
Allowing for inevitable sampling and translation variations in the national surveys, the data show that the English-speaking countries—headed by the U.S.—tend to be more sanguine about science (between two-fifths to more than one-half are positive) than are the continental European countries, which range around one-third positive. The exceptional positions of Japan and The Netherlands remain unexplained at this point.

The data also show that Western democracies closely resemble each other in the proportion of their populations which believes that in the long run, science is harmful to mankind—around 20 percent.

Historical experience from U.S. surveys shows that very general attitudes such as the one displayed here do not change very quickly over time. As comparative studies in this field develop, they can be expected to reveal interesting and important relationships between national public attitudes and public policies toward S/T.

Figure 0-33.

**Public perceptions of benefits and harms from scientific advance in selected countries: 1981-83**




Note Responses to the question "In the long run, do you think the scientific advances we are making will help or harm mankind?"

See appendix table 8-9 and p. 148. Science & Engineering Indicators — 1987



31

# Chapter 1
# Precollege Science and Mathematics Education

# Precollege Science and Mathematics Education

## HIGHLIGHTS

- *Movements for educational reform are abundant.* Each of 50 State Governments has launched measures aimed at improving teacher supply or quality, enhancing course-taking in science and mathematics, or other similar policies to upgrade student performance. (See pp. 29-32.)
- *The problem solving ability of elementary and secondary students in science and mathematics remains at low levels.* Scores on the latest national assessment of mathematics show that students' problem solving/reasoning ability has declined, while their ability to solve problems requiring routine computation and rote memory has increased. (See p. 21.)
- *Although blacks and Hispanics scored well below their white counterparts* in all assessments and in all age groups, the most pervasive gains were by black students. By 1987, black 13-year-olds surpassed Hispanics in mathematics achievement. (See p. 21.)
- *American students perform relatively poorly in international assessments of science and mathematics.* Even our best mathematics students have the lowest achievement scores of any country for which comparable data are available. (See p. 24.)
- *It is doubtful if there is an adequate supply of teachers.* The grandchildren of the post-war "baby boom" are now entering school and, as a result, enrollment in elementary school is on the upswing. Teacher supply is down, especially among young college-educated women and minorities, and many teachers are approaching retirement age. (See pp. 27-29.)
- *Teacher preparation and qualifications reveal serious inadequacies.* Only one in three elementary science teachers has had a college chemistry course and only one in five a college physics course. (See pp. 25-27.)
- *More than one-half of all secondary school science teachers has never had a college course in computer science* and almost one-half has had no college calculus. (See pp. 25-27.)
- *Gender and race continue to be negatively correlated with school performance in science and mathematics.* Girls generally take less course work in mathematics and physical science than boys, although they equal boys in time spent in classroom biology. Enrollment of minorities (except for Asians) is much lower in science and mathematics than enrollment of whites. (See pp. 21-24.)

Throughout our Nation's history, we have placed a high priority on establishing educational policies to ensure an informed and educated citizenry. For example, the importance of advanced technical education to the economy was recognized more than 100 years ago with the enactment of the Land Grant College system.

After the Second World War, the new U.S. role in international defense placed additional strong demands on science and engineering (S/E) education. Further spurred by the Soviet launch of Sputnik, the Federal Government helped stimulate the expansion of the S/E workforce by supporting academic S/E education.

More recently, policymakers have become concerned regarding America's competitive position in the world economy. It is becoming increasingly evident that strength in science and technology is a precondition for economic competitiveness. Consequently, there is a national need for careful nurturing of scientific, mathematical, and engineering education at all levels.

Since the early 1980's, copious national reports have been released on various aspects of education in the U.S. Most have concluded that there are serious problems in our precollege science and mathematics education. Among the most prominent problems identified in these reports are:

- Academic performance is inadequate.
  - —There is great disparity in achievement among ethnic groups and between boys and girls; and
  - —U.S. high school students overall are less skilled in science and mathematics than some of our international competitors, especially the Japanese.
- The teaching force is inadequate.
  - The proportion of noncertified teachers in certain fields of science and mathematics is relatively high, and
  - The supply of new science and mathematics teachers has diminished and the number of graduates entering the teaching profession has also declined.
- The curriculum is inadequate.
  - Many students are "turned off" because of the routine nature of the subject matter, and
  - Rote skills rather than "higher order" analytic skills are taught.

Each of these problems is examined in the following sections of this chapter.

## STUDENT ACHIEVEMENT AND PARTICIPATION

In the 1985/6 academic year, the National Assessment of Educational Progress (NAEP) again tested national samples of 9-, 13-, and 17-year-olds in mathematics, science, and—for the first time—computer competence. These test results permitted examination of trends in mathematics since the 1977/8 academic year[1] and trends in science scores since 1976/7.

### Mathematics Achievement

Overall, there have been no statistically significant trends in the mathematics scores for the total sample since 1978. There have, however, been some significant changes from one assessment to the next, especially when subpopulations are examined. For example, the trend for the 13-year-olds turned downward in the most recent assessment (see figure O-16 in Overview), and that for male 9-year-olds swung upwards. (See appendix table 1-1.)

The most pervasive gains in mathematics achievement were displayed by black students, who gained—without exception—from 1978 to 1986. The 13-year-old blacks increased from 48 percent correct to 57 percent correct and in so doing surpassed the Hispanics in 1985/6. The 13-year-old Hispanics dropped significantly in the latest period, perhaps because of a substantial increase in their number and—with the increase—a likely increase in the number whose best language is other than English.

Analysis of subgroups of the mathematics items shows that those items designed to measure higher-level applications (problem solving/reasoning), routine applications, and understanding/comprehension tended to display downward trends; on the other hand, items reflecting skill (routine manipulation) and knowledge (mostly memory) and items measuring skill in using a calculator tended to display upward trends. These results suggest that teachers have responded to the demand for better performance by requiring more practice on routine computations and rote memory.

Biographical information provided by NAEP subjects indicates that the precollege student population changed from 1982 to 1986 in many ways, some of which may have had important implications for math and science education. At all three age levels, a smaller proportion of the sample subjects reported that their parents had only a high school education and a larger proportion reported they were college graduates. The 17-year-olds reported an increase in television watching (the 9- and 13-year-olds were not asked). The number watching TV 3 or more hours a day increased from 27 percent in 1978 to 36 percent in 1982 and 56 percent in 1986. This increase may have impaired achievement: "hours of watching" is negatively correlated with achievement. However, "time spent on homework" also increased, the percentage reporting 1 or more hours increased from 29 percent to 37 percent to 66 percent. This increase in homework may have counteracted the negative effect of television watching. Perhaps of more importance as far as the math achievement of 17-year-olds is concerned, the 1985/6 subjects reported a small increase in enrollments in intermediate and advanced mathematics (from 57 percent to 61 percent in geometry, algebra II, and calculus) and a small decline in the percentage who reached only pre-algebra or algebra I (from 40 percent to 37 percent). The increased mathematics enrollments coincided with the increase in achievement for 17-year-olds.

Changes in enrollment were especially evident for black students, whose enrollment in pre-algebra and algebra I increased slightly from 1978 to 1982 (50 percent to 54 percent) and then fell from 1982 to 1986 (54 percent to 45 percent). Further, the percentage reaching geometry, algebra II, or calculus dropped slightly in the first period (from 42 percent to 41 percent) and then increased substantially in the second (from 41 percent to 48 percent). These overall gains in mathematics enrollments may well explain gains in achievement by blacks.

### Science Achievement

The national results for science achievement in general parallel those of mathematics except that the 13-year-olds did not display a downswing from 1982 to 1986. (See figure O-17 in Overview and appendix table 1-2.) Both males and females gained, as in former assessments, the females had higher means at 9 years (with the exception of 1976/7) and the males had higher means at the 13- and 17-year levels.[2] The difference between males and females converged slightly from 1982 to 1986 (by 0.3 percentage points for the 13-year-olds and 0.6 percentage points for the 17-year-olds).

White, black, and Hispanic students each gained except for 13-year-old Hispanics who declined slightly in science achievement from 1982 to 1986. Both blacks and Hispanics continued to perform appreciably less well than whites although the gap between blacks and whites decreased slightly, by 2 percentage points at each age level.

### Computer Competence

In a new effort, the computer competence of 9-, 13-, and 17-year-olds was assessed in 1986. Computer competence was defined as general knowledge of computers and understanding of the concepts behind computer operation, familiarity with computer applications, and programming ability. The NAEP staff concluded that overall computer competence in primary and secondary schools was "markedly lower than expected or desired," that "students with the greatest proficiency are those who have most exposure to computers at home and at school," and that students who come from families with

[1]Although a national assessment of science was conducted in 1969/70 and in mathematics in 1972/3, for technical reasons these results are not comparable with data for later years.

[2]Nine-year-olds were not tested for science content in the 1982 survey. The data for 1982 shown here are based on achievement of 9-year-olds on inquiry and science-technology and society items in 1982, weighted in proportion to the number of items on each scale, as a proxy for what achievement on content items might have been.

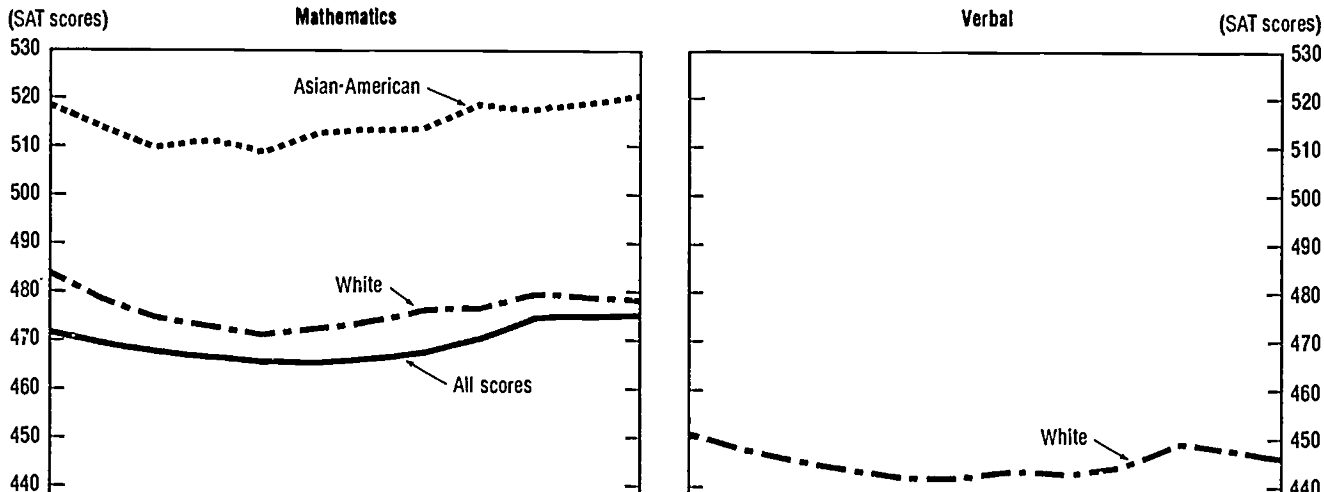
"high socioeconomic status are also among the best achievers." At all levels, males had somewhat higher scores than did females; white students outperformed both black and Hispanic students.

### Students Intending to Major in S/E Subjects

Students who intend to major in science or engineering generally score much higher on Scholastic Aptitude Tests (SAT's) —both on the math and verbal portions— than do all students taking these tests. During 1975-86, however, SAT scores for students planning an S/E major declined. (See appendix tables 1-3 and 1-4.) This approximately paralleled the declines for the total SAT population. Mean SAT quantitative scores for students intending to major in S/E disciplines declined from 520 in 1975 to 507 in 1981, then rose to 513 in 1986. SAT verbal scores for the same group were 464 in 1975, 444 in 1983, and 450 in 1986. As was the case in NAEP studies, males scored higher than females: in 1986, white males scored 546 on the SAT quantitative test compared with 496 for white females. Black males averaged 417 compared with 382 for black females.

For students intending to major in science and engineering, the highest SAT quantitative scores were for students intending to major in physical sciences (598),

Figure 1-1.
**Average SAT scores for college-bound seniors, by ethnic group**




See appendix table 1-5.

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followed by mathematics and statistics majors (593). Similarly, students intending to major in physical sciences scored highest (526) on the SAT verbal test.

### College-Bound Seniors

Although most minority groups traditionally score much lower than do whites, the verbal and quantitative SAT score averages of college-bound minorities have risen since the late 1970's, especially for black, Mexican-American, and Puerto Rican students. Moreover, Asian-American students score higher than do whites on the SAT quantitative test; while this is not paralleled by their SAT verbal results, Asian-Americans do score higher on the verbal test than do the other three minority groups. (See figure 1-1.)

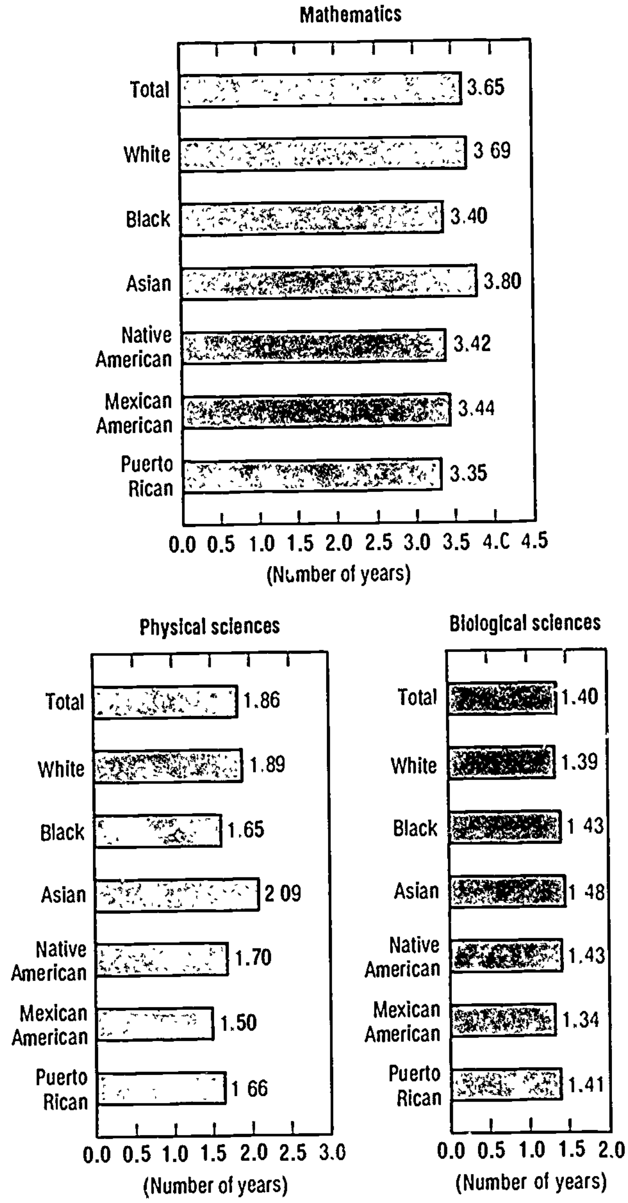
The chief reason most minority groups score relatively low on the SAT quantitative tests is that enrollment in high school mathematics courses varies considerably by ethnic group, with that of Asian students being significantly higher than enrollment by other minority groups. (See figure 1-2.)

Several explanations for the Asian-American performance pattern have been suggested, including the fact that most foreign-born Asian-Americans in S/E occupations come from the more affluent classes in their countries and may have experienced more favorable educational and social opportunities than their American-born counterparts. Additional suggested explanations include cultural differences in the Asian-American home, an English language difficulty which leads students to seek academic fulfillment in subjects based on the universal language of mathematics, and positive role models in the Asian-American community.[3] It has been noted too that Asian-American mothers have an unusually high level of education. Finally, it has also been suggested that relatively high quantitative ability differs by generation after immigration to the U.S., since American-born Asian-Americans of second, third, and fourth generations are underrepresented in S/E.[4]

Math disadvantage for black students begins in elementary school and continues into high school where students select courses in one of three basic curricula: academic, general, and vocational.[5] White students are overrepresented in the academic curriculum, while black and Hispanic students are overrepresented in both the general and vocational curricula, which require only lower-level mathematics classes. Even in the academic curriculum, however, where students are likely to enroll in advanced mathematics courses, 79 percent of the white high school students participated in advanced mathematics courses in 1982 compared to only 55 percent and 54 percent, respectively, of the black and Hispanic students.[6]

College-bound men and women differ in SAT verbal test scores only by about 12 points. (See figure 1-3.) There

Figure 1-2.
**Average number of years of study for college-bound students, by ethnic group: 1984**




SOURCE Betty M Vetter, "Attitudes, Participation and Achievement of Women and Minorities in Precollege Science and Math Education," unpublished report to the National Science Foundation (May 1986)

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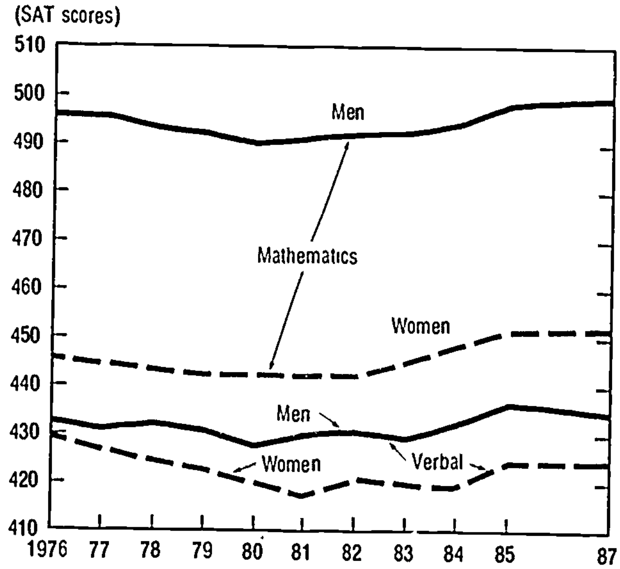
is, however, a 47-point difference between women's and men's SAT quantitative scores, a difference which has existed for at least 15 years. While this wide gap does not seem attributable only to the relatively small difference in mathematics course enrollment (see figure 1-4), no other satisfactory explanation has yet been advanced. Girls do take less course work in mathematics and physical sciences, but they slightly surpass boys in the amount of time spent in biology classes.

[3] Vetter (1986), p. 16.
[4] Statements by Dr. Robert Suzuki before the U S Congress, House Committee on Science and Technology, U S Congress (1982), p 12
[5] Davis (1986), pp. 26-30
[6] Ibid., p. 26.

Figure 1-3.
**Average SAT scores for college-bound seniors, by gender**




See appendix table 1-5.

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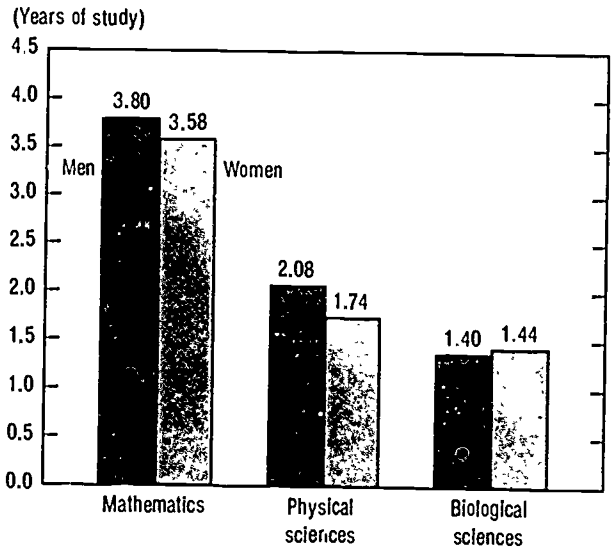
Figure 1-4.
**Average number of years of study for college-bound students by gender: 1985**




SOURCE: Betty M. Vetter, "Attitudes, Participation and Achievement of Women and Minorities in Precollege Science and Math Education," unpublished report to the National Science Foundation (May 1986)

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## International Comparisons of Achievement Test Results

U.S. students do not do well on science and mathematics achievement tests when compared with other countries studied. For example, an international survey conducted in 1981-82 compared the achievement in functions and calculus of the top 1 percent and 5 percent of 12th-grade college preparatory mathematics students in 13 countries. (See figure O-15 in Overview and appendix table 1-6.) The most able Japanese mathematics students attained higher scores than their counterparts in other countries in both subjects. Perhaps more significantly, the average Japanese student achieved higher scores in functions and calculus than the top 5 percent of the U.S. students in college preparatory mathematics. Additionally, the most able (top 1 percent) U.S. students scored the lowest of all 13 countries in algebra and were among the lowest in calculus.[7] The algebra achievement of the U.S. top 5 percent group was lower than that of any other country except Israel.

For students in the eighth grade, five content areas were tested: arithmetic, algebra, geometry, statistics, and measurement. The U.S. scored at or near the international average for three of these topics: arithmetic, algebra, and statistics. On the remaining two topics, the U.S. scores were among the lowest one-quarter of the countries.[8]

## Top Mathematics Test Scorers

Of high school seniors who scored above the 90th percentile on the SAT quantitative examination in 1986, about 44 percent intend to study science or engineering in college. (See appendix table 1-7.) More than one-half of the males who score in the 90th percentile plan to study science or engineering (see figure 1-5), while only about one-third of the high-scoring females are interested in S/E as a college major.

Over the last decade, top test scorers have exhibited an overall declining interest in majoring in mathematics and science and an increasing interest in an engineering major. (See figure 1-6.) Even though the percent of high-scoring students interested in a business major has increased between 1984-86 from 18 to 21 percent, this increase does not fully explain the declining interest in mathematics and science. Pre-med is also declining as are many smaller fields (not shown on the graph), such as other health fields and the humanities.

In the past few years, increasing numbers of examinees have indicated that they are undecided about their major field. There does not seem to be any one field drawing students away from mathematics and science, although undoubtedly business and engineering have attracted more high-scoring students in the past 2 years than they did previously.

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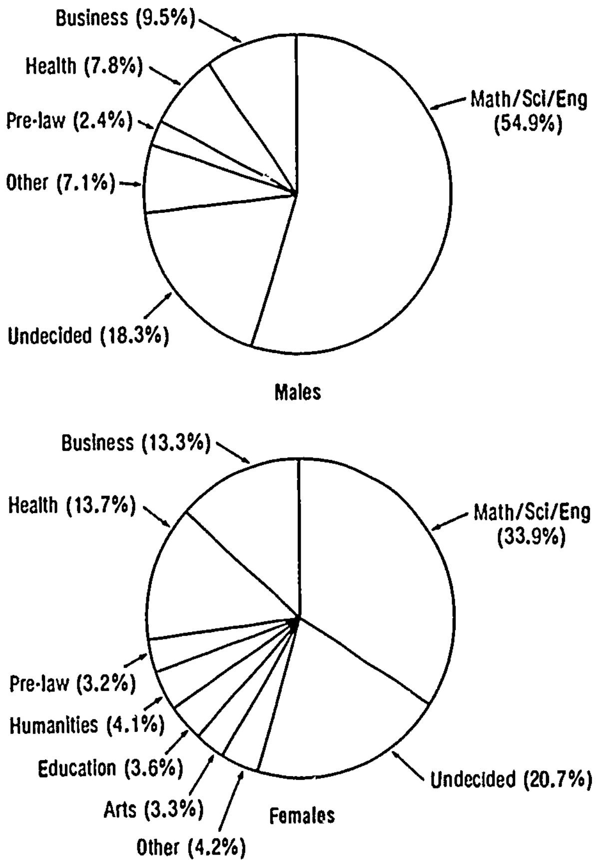
[7]International Association for the Evaluation of Education Achievement (1987), p. 26.
[8]Ibid., p. 21.

Figure 1-5.
**Major field selections of high school seniors scoring above the 90th percentile on SAT math**




SOURCE: Jerilee Grandy, "Trends in Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," unpublished report to the National Science Foundation, Educational Testing Service (March 30, 1987)

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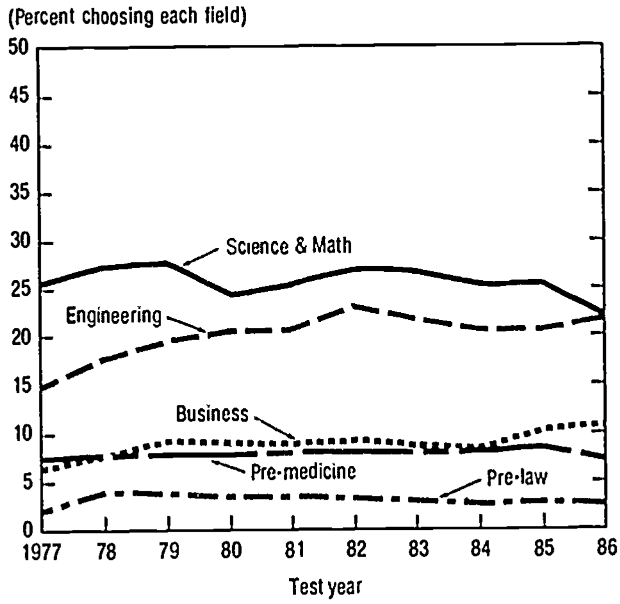
Figure 1-6.
**Major field selections of examinees scoring above the 90th percentile on the SAT mathematics examination**




See appendix table 1-7

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Trends over the past 10 years in the 90th percentile cutoffs look encouraging for the population as a whole and for each of the race/gender subgroups. (See appendix table 1-8.) SAT math scores for the top 10 percent rose from 623 to 642 in the last 5 years. The increase in minorities' scores is especially impressive. For instance, since 1979, the 90th percentile mathematics scores for both black males and females have increased 27 points.

## Expected Majors of College Freshmen

A useful indicator of interest and secondary school participation in science and mathematics courses is the stated expected majors of freshman college students. These data are collected early in the freshman year, often during orientation programs, and therefore are likely to reflect precollege expectations and interests.

The percentages of women students who anticipate that they will choose a science, engineering, or mathematics major have not changed substantively over the 1975-85 period, ranging from 18 to 20 percent. (See figure 1-7 and appendix table 1-9.) In contrast, men students have been reporting an increasing likelihood that they will opt for these majors—up from about 30 percent in 1975 to a high of 38 percent in 1983, but declining to 34 percent in 1985.

After a peak in 1977, there has been a long-term decline in the number of high school graduates. Therefore, the actual number of bachelor's degree students from whom graduate scientific and technical careers might be expected may also decline unless more interest can be generated among precollege students.

## TEACHER CHARACTERISTICS

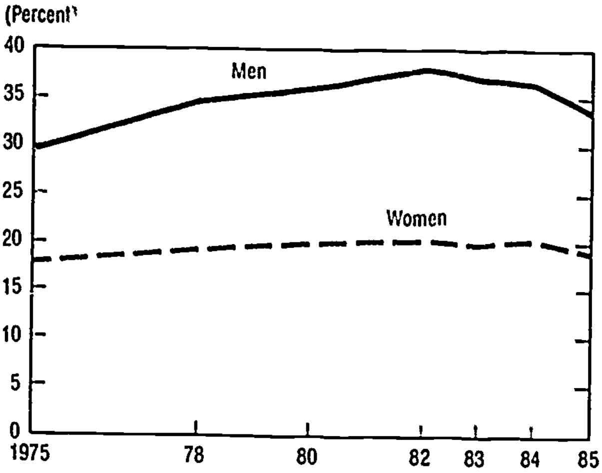
Characteristics of the Nation's precollege teaching force reveal several causes for concern. For example, teaching recruits historically have been drawn from among the least able college graduates. Furthermore, the standardized test scores of these teacher candidates declined throughout the 1970's.[9] Although a number of academically talented people pursue careers in teaching and teacher education, these remain underrepresented in the field. As a result, teacher education tends to be relatively easy and nonchallenging.[10]

[9] Sykes (1983). See also National Science Board (1986), p. 136

[10] Lanier (1984).

Figure 1-7.

**Percent of freshmen at all U.S. institutions of higher education whose probable major field will be science or engineering**




Note: "Science or engineering" includes only the following majors: biological sciences, engineering, mathematics, statistics, computer science, physical sciences, and the social sciences.

See appendix table 1-9. Science & Engineering Indicators — 1987

In 1985-86, two national reports were issued focusing on the training and employment conditions of K-12 teachers. One of these studies, sponsored by the Carnegie Corporation,[11] targeted the enhancement of K-12 teaching as a profession. Recommendations included toughening certification standards, increasing salaries, and improving working conditions. Other recommendations were to develop "lead teachers," eliminate undergraduate programs in teacher education, develop new graduate-school programs leading to master's degrees in teaching, create a National Board for Professional Teaching Standards, restructure K-12 schools to allow teachers greater discretion in achieving State and local goals, increase teacher accountability for student performance, and increase efforts to recruit minority teachers.

A second report[12] (prepared by the so-called Holmes Group—the deans of schools of education at research universities) concentrated on teacher education. Some of its recommendations coincide with those made by the Carnegie study: increase teaching professionalism, increase salaries, abolish the undergraduate education degree, and place more emphasis on graduate education for prospective teachers.

As both studies indicate, the relatively low salary offered teachers creates a serious problem: it is, in fact, one of the primary reasons that the teaching profession at the precollege level has not been able to attract and retain more academically able professionals. Although teacher salaries have begun to rise after a general decline during the 1970's, they typically have been lower than those for most other fields requiring a bachelor's degree. (See appendix table 1-10.)

An important shift recently has occurred in the social makeup of science and mathematics teachers. Traditionally, most elementary teachers have been female and the proportion of male teachers has increased with grade level. Since 1977, however, there has been an overall decrease in the proportion of male science and mathematics teachers. For instance, in 1977, more than two-thirds of mathematics teachers in grades 10-12 were male; in 1985/6, this proportion fell to a little more than 50 percent. (See appendix table 1-11.) It is not yet clear what the implications of this shift will be on the quality of science and mathematics teaching and on opportunities for student "role modeling."

Teachers' racial and ethnic makeup may also be significant in providing role models for minority students. The proportion of minorities who taught science and mathematics in 1985/6 was generally low, particularly in middle school and senior high school. Specifically, only 1 percent of grade 10-12 science and mathematics teachers were Hispanic and from 3 to 6 percent were black. (See appendix table 1-12.)

## Courses Taken by Science and Mathematics Teachers

A profession's quality can be indicated by comparing standards established by professional groups to credentials attained by practicing members of the profession. The National Science Teachers Association (NSTA) has recommended that elementary science teachers have at least one college course in the biological sciences, one course in the physical sciences, and one course in the earth/space sciences. About 33 percent of the K-3 science teachers and 40 percent of 4-6 teachers meet that standard.[13] While about 85 percent of elementary school teachers have taken at least one college course in the biological sciences, only about one in three has had a chemistry course and only one in five has had a physics course. (See appendix table 1-13.)

NSTA also recommends that junior high school science teachers have at least 36 credit hours in science, and senior high school teachers have at least 50 credit hours. Assuming that each science course averages 3.5 credit hours, more than 65 percent of 7-9 science teachers and more than 80 percent of 10-12 science teachers meet or exceed that standard; 40 percent of 7-9 science teachers and almost 60 percent of 10-12 science teachers meet or exceed the 50 credit hour standard. (See figure 1-8.)

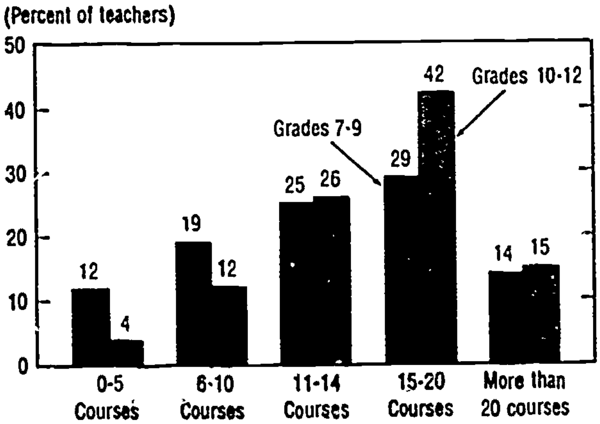
Nearly all of the 7-9 science teachers (97 percent) and the 10-12 teachers (93 percent) have taken a college course in biology. Almost one-half of 7-9 science teachers and two-thirds of 10-12 teachers have taken eight or more life science courses. (See appendix table 1-14.) Similarly, while large proportions of 7-9 science teachers (76 per-

[11] Task Force on Teaching as a Profession (1986).

[12] National Commission for Excellence in Teacher Education (198?).

[13] Data in this subsection are from the 1985/6 National Survey of Science and Mathematics Education conducted for NSF by the Research Triangle Institute.

Figure 1-8.
**Sciences courses completed by secondary science teachers: 1985**




Note: Since the highest number of courses a teacher could indicate for each of the 4 categories — life science, chemistry, physical/physical science, and earth/earth science — was "more than 8," these figures underestimate the totals for any teachers who completed more than 8 courses in a particular category.

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Graduation*

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cent) and 10-12 teachers (73 percent) have had at least one college-level course in the earth/space sciences, only 12 percent of the former and 6 percent of the latter have had eight or more courses in these areas. More than one-half of all secondary science teachers have never had a college course in computer science, almost one-half have had no college calculus.

In most of the fields of science and mathematics, sizable proportions of the teachers have taken one or more courses in specialized subfields over and above the general introductory course in the field. (See appendix table 1-15.) The exception is physics, where substantially fewer teachers have been exposed to specialized courses.

While 90 percent of K-6 mathematics teachers have had a mathematics course specifically for elementary school teachers, only 20 percent have had a course in geometry for teachers, 25 percent a course in probability and statistics, and 10 percent a college calculus course. (See appendix table 1-16.)

The National Council of Teachers of Mathematics (NCTM) recommends that junior high school mathematics teachers complete one calculus course, one computer science course, and one or more courses in teaching mathematics. Sixty-nine percent of grade 7-9 mathematics teachers meet or exceed the calculus recommendation, 60 percent have had a course in computer science, and 84 percent have had one or more courses in methods of teaching mathematics. (See appendix table 1-17.) At the 10-12 level, two-thirds (66 percent) of the teachers have had at least three calculus courses as suggested by NCTM, three-fourths have had a college course in computer science, but only 55 percent have had two or more courses on teaching methods. While two-thirds of 7-9 mathematics teachers and four-fifths of 10-12 teachers have had a college-level geometry course, and nearly an equal proportion have had a course in probability and statistics, fewer than 40 percent of each group has had a course in the applications of mathematics and only about one-third has had a course in the history of mathematics.[14]

### Teachers' Perceptions of Their Qualifications to Teach

Elementary school teachers feel less well qualified to teach science than any other subject. This perception remained about the same between 1977 and 1985/6. In 1977, most elementary teachers indicated that they felt very well qualified to teach reading (63 percent); corresponding figures were 49 percent for mathematics, 39 percent for social sciences, but only 22 percent for science. (See table 1-1.) By 1985/6, teachers' confidence in their ability to teach mathematics, social studies, and reading had increased, but remained at about the same low level for the sciences. Science subjects were the only ones in which more than 4 percent of the teachers surveyed indicated that they felt "not very well qualified." When asked to name a specific science topic that they would find difficult to teach, teachers most commonly listed physics, chemistry, and—to a lesser extent—earth/space sciences topics.

At the secondary level, 13 percent of all science teachers felt in 1977 that they were inadequately qualified to teach science. By 1985/6, only 7 percent of secondary science teachers felt inadequately qualified. (See appendix table 1-18.)

One way to help remedy these feelings of inadequacy—and help teachers keep up with changes in their fields—is to provide opportunities for continuing (in-service) education. The survey data show, however, that between one- and two-fifths (depending on the grade level they teach) of science and mathematics teachers have not taken a course for college credit in their subject for the last 10 years. Moreover, while many teachers have participated in professional meetings, workshops, and conferences related to science or mathematics teaching, the amount of time devoted to in-service education activities was typically less than 6 hours during the year prior to the survey. (See appendix tables 1-19 and 1-20.)

## TEACHER SUPPLY AND QUALIFICATIONS

A recent survey of teacher placement officers reported that, in the fields of math, physics, chemistry, bilingual education, multiply handicapped, and mental retardation, there is now a considerable shortage of teachers.[15] Will there, then, be enough qualified candidates to meet the demand for classroom teachers in the future? (See figure 1-9.) With student enrollments projected to increase and retirements expected to accelerate, more teachers will be needed each year. This demand for new

[14] Research Triangle Institute (1986).
[15] Akin (1986).

Table 1-1. Elementary teachers' perceptions of their qualifications to teach various subjects: 1977 and 1985/86

| Subject | Percent perceiving that they are: Not well qualified | Adequately qualified | Very well qualified | No answer |
|---|---|---|---|---|
| | 1977 | | | |
| Mathematics | 4 | 46 | 49 | 1 |
| Social studies | 6 | 54 | 39 | 1 |
| Reading | 3 | 32 | 63 | 2 |
| Science | 16 | 60 | 22 | 2 |
| | 1985/86 | | | |
| Mathematics | 1 | 30 | 67 | 2 |
| Social studies | 4 | 47 | 47 | 2 |
| Reading | 1 | 15 | 82 | 2 |
| Life science | 11 | 60 | 27 | 2 |
| Physical science | 23 | 59 | 15 | 3 |
| Earth/space sciences | 22 | 59 | 15 | 4 |

SOURCE: Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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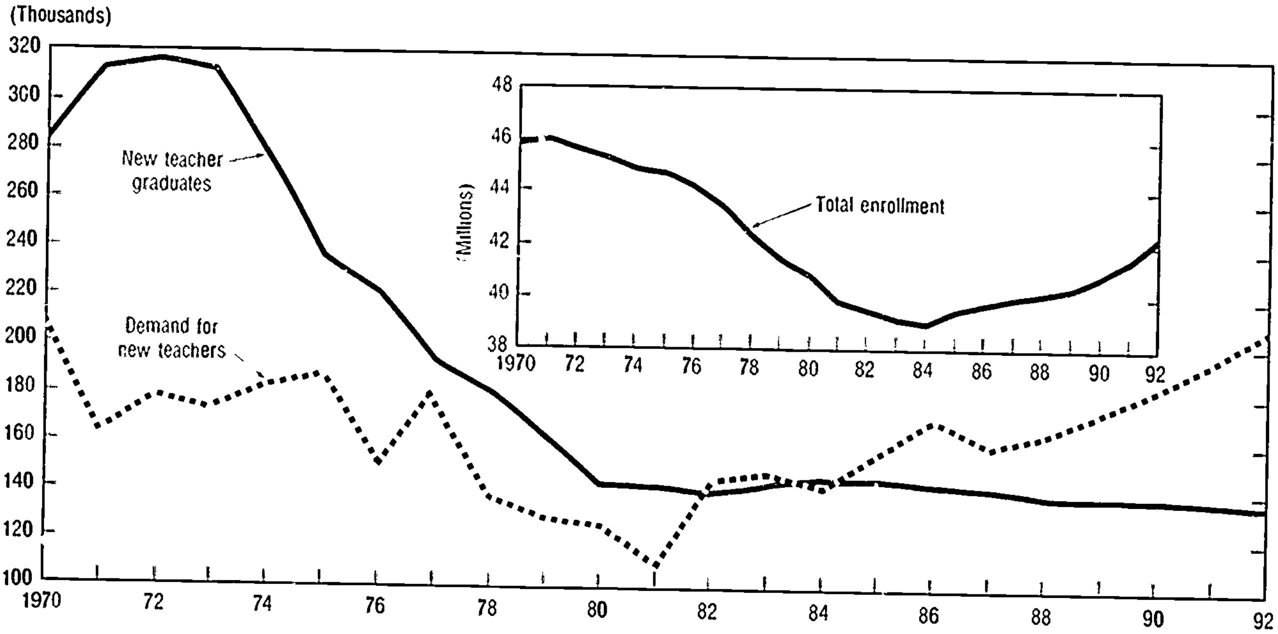
Figure 1-9.

New hires in teaching[1] and new teacher graduates,[2] and total enrollment




[1]Data through 1983 are actual new hires. Data for 1984-93 are the intermediate value of three alternative projections
[2]Data through 1984 are actual new hires. Data for 1985-93 are the intermediate value of three alternative projections
Note: Data are for the school year beginning in the autumn of the given calendar year
See appendix tables 1-21, 1-22 and 1-23

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hiring will, because of enrollment increases, affect elementary and secondary levels at different times: elementary school teacher hiring is expected to increase from the mid-1980's into the early 1990's before declining. The demand for new hiring of secondary school teachers is expected to increase from the late 1980's into the early 1990's.

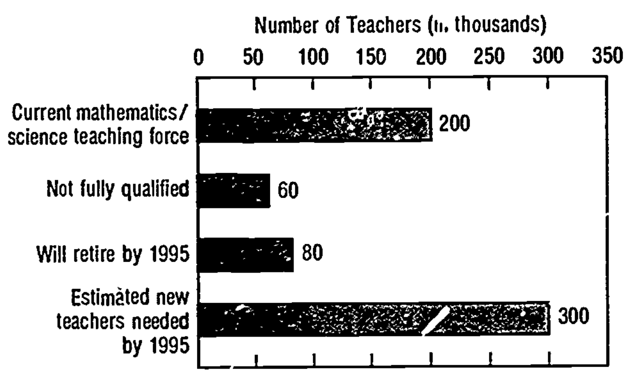
Recent reviews of mathematics and science teacher shortages conclude that misassignment is a major cause of the shortages of qualified teachers in these subject areas.[16] Such misassignment occurs more frequently in

[16]Rumberger (1984)

physics and chemistry than in the biological sciences.[17] According to NSTA estimates, approximately 30 percent of all secondary mathematics and science teachers are either "completely unqualified or severely underqualified" to teach these subjects. Further, more than 40 percent of the total mathematics and science teaching force will retire by 1992.[18] (See figure 1-10.)

Studies show that during the 1970's the proportion of women receiving bachelor's degrees in education decreased by one-half, while the proportion of degrees granted to women in the biological sciences, computer science, engineering, and law increased tenfold.[19] Many of these women were among the most academically able and well-prepared members of the new bachelor recipients.[20] In addition to this loss of more academically trained teachers, current and impending teacher shortages may further detract from teaching quality. Given the projected high level of demand, two hiring patterns for mathematics and science teachers may become prevalent. First, there may be even more reassignment of less qualified teachers from other subject areas to mathematics and science courses. Although these individuals may be generally competent teachers, given the weakness and/or nonexistence of in-service retraining programs, mathematics and science teachers trained in their area of instruction would be preferable to those trained in other subject areas. Second, a full complement of new mathematics and science teachers may be hired. This might have other drawbacks since such new, inexperienced teachers may be less effective[21] and may be more likely to leave teaching.[22]

Figure 1-10.
**Status of the mathematics and science secondary-school teaching force**




SOURCE: National Science Teachers Association survey in December 1982, reported in Hope Alrich, "Teacher Shortage: Likely to Get Worse Before It Gets Better," *Education Week* (July 27, 1983)

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## TEACHER REFORM MOVEMENTS

A recent national report about teaching as a profession stated that, "The 1980's will be remembered for two developments: the beginning of a sweeping reassessment of the basis of the Nation's economic strength and an outpouring of concern for the quality of American education."[23] This concern about the quantity and quality of teachers in K-12 education—especially in science and mathematics—has led both States and teacher education institutions to undertake a variety of corrective measures affecting how teachers are trained and certified, what they are paid, how their skills are maintained and enhanced, and the conditions under which they work. While relatively few of these initiatives are directed solely at science and mathematics teachers, the primary focus of concern is on this group of teachers. These initiatives are discussed below; it should be noted, however, that many of the reforms have only been undertaken in the last 4 years and their effectiveness cannot yet be fully gauged.

### State Reforms

Between 1980 and 1984, all 50 States and the District of Columbia had launched at least one action to promote either the quantity or quality of elementary and secondary school teachers.[24] Altogether, 48 States have one or more initiatives designed to increase the supply of teachers; 44 States have at least one quality-related initiative.

The most popular forms of State initiatives for increasing teacher supply are those designed either to lower the cost to the student of teacher training (38 States) or increase the benefits of being a teacher (38 States). Student costs are decreased primarily through loan forgiveness or other student financial programs. Teacher benefits are increased through raises, better working conditions, or greater social recognition. Twenty-six States have both lowered costs and increased benefits. (See figure 1-11.)

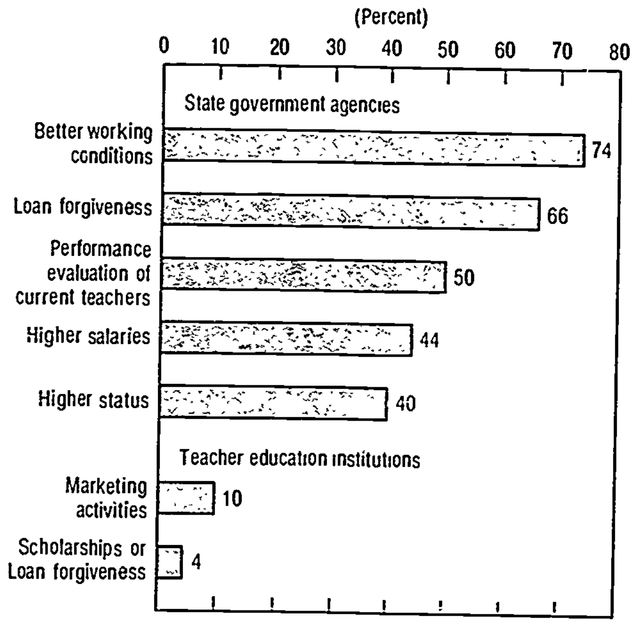
State initiatives designed to enhance teacher quality include: more provisions for further training of current teachers (28 States), higher admissions requirements for entry to teacher education programs (26 States), tougher teacher certification requirements (25 States), and performance evaluations of current teachers (25 States). (See figure 1-12.)

State teacher quantity initiatives have focused on potential or actual teacher pools, rather than on teacher training processes, because a major problem is lack of interest or incentive for individuals to enter the teaching profession. As a whole, tne Nation has experienced declines in its teacher supply: it is anticipated that, in 1992, the supply of newly graduated teachers will fill only two-

[17]Johnston and Aldridge (1984).
[18]Ibid.
[19]U.S. Department of Commerce, Bureau of the Census (1983 and 1973).
[20]Vance and Schlechty (1982), pp. 22-27.
[21]Rosenholtz (1984), pp. 352-388.
[22]Murnane (1985).
[23]Task Force on Teaching as a Profession (1986), p. 11.
[24]Education Commission of the States (1984).

Figure 1-11.

**Percent of State government agencies and teacher education institutions which initiated policies and programs between 1980 and 1985 to enhance the number of teachers**




SOURCE Surveys conducted by the Education Commission of the States. Council on Education, reported in Paul T Brinkman and Dennis P Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986)

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thirds of the available positions.[25] In addition, based on preliminary analyses, it appears that the attrition rate of chemistry, physics, and foreign language teachers is higher than that of other teaching fields; also, chemistry and physics teachers who leave the teaching profession are less likely to return to it.[26]

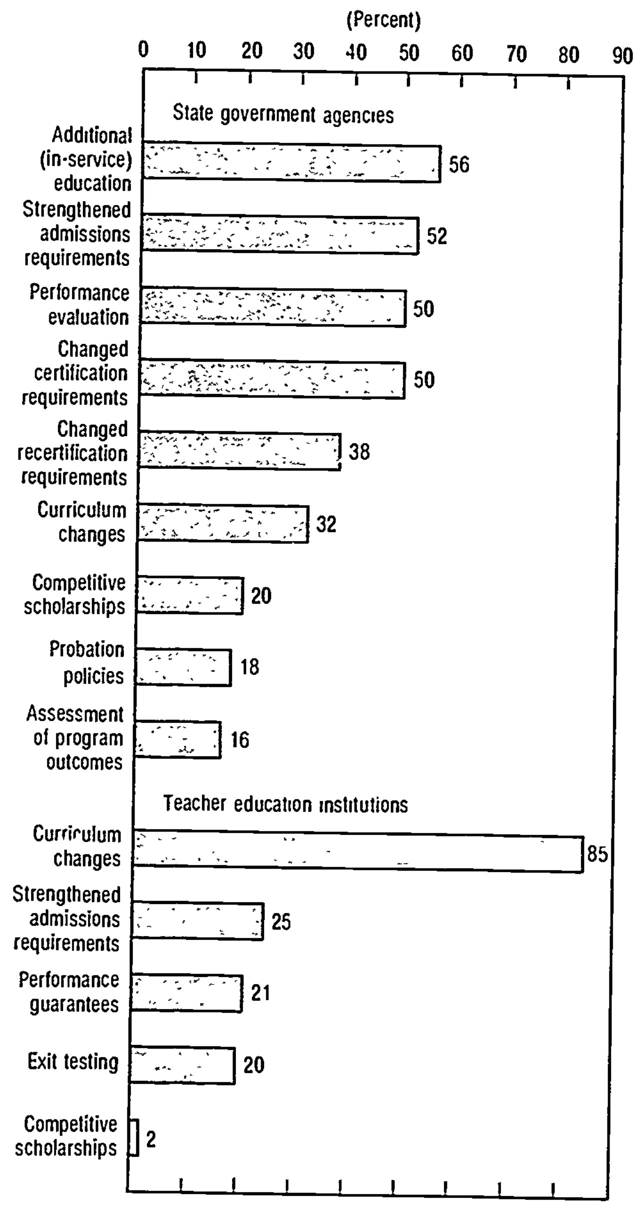
Teacher quality initiatives can be grouped into three categories: those directed toward potential teachers, those involving certification of current teachers, and those aimed at the process of teacher education. Among the 44 States with recent quality-related initiatives, potential teachers are the target in 26 States, current teacher certification is the target in 35 States, and the training process is the target in 34 States. In 12 States, two of the three objectives have been targeted; in 20 States, all three objectives are receiving attention.

Potential Teachers

The most frequent form of quality-related initiatives directed toward potential teachers is higher admissions requirements for entry into teacher education programs (26 States), competitive scholarship programs have been added in 10 States.

Figure 1-12.

**Percent of State government and teacher education institutions which initiated policies and programs between 1980 and 1985 to enhance the quality of teachers**




SOURCE Surveys conducted by the Education Commission of the States, Council on Education, reported in Paul T Brinkman and Dennis P. Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986)

[25] Darling-Hammond, et al. (1987), p. v.

[26] Murnane and Olsen (1987).



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### Certification

New initiatives focusing on certification relate either to the certification of new teachers (25 States), or the recertification of current teachers (25 States). Competency testing—the main purpose of which is to screen out candidates deficient in basic skills and knowledge—is one approach to regulate entry into the teaching profession. As of 1986, 35 States had required competency testing as part of the process for initial teacher certification. (See appendix table 1-24.) Two States (Arkansas and Texas) had instituted testing for recertification of experienced teachers. In its recent report, the Carnegie Forum proposes a three-stage voluntary assessment process covering subject matter, education courses, and teacher performance—all under the aegis of a National Board for Professional Standards.

### Teacher Education

Staff development of teachers is the most prevalent focal point of new State initiatives that attempt to enhance quality by changing the teacher training process. Some form of this type of initiative—such as providing funding, establishing training centers, or setting minimum standards for number of hours of training—has occurred in 28 States. Sixteen States have initiatives directed toward aspects of the training curriculum for new teachers; an additional eight states have taken steps to evaluate the outcomes of teacher education programs, primarily by comparative statistics on competency exam results. Nine States have initiatives designed to influence activities during a teacher's first years in the profession (sometimes referred to as an internship or probationary period).

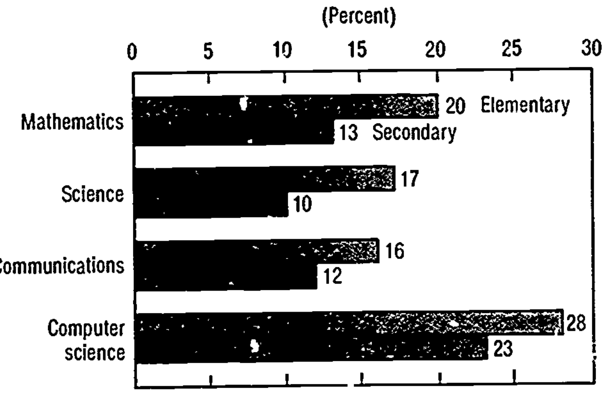
### Higher Education Reforms

Higher education institutions also have undertaken efforts aimed at reforming teacher quality/quantity. These have primarily involved efforts to attract students to teaching careers,[27] and include such marketing activities as visits to high schools and mailings of brochures (10 percent of the institutions) and additions of new scholarships or loan forgiveness programs (4 percent) (See figure 1-11.)

Another aspect of teacher education reform involves standardized tests for entry into teacher education, which have proliferated dramatically over the last 5 years.[28] At the beginning of the eighties, less than one-quarter of all institutions of higher education required these tests; by 1985, however, nearly one-half of them did. Public institutions are more likely than private ones to invoke entrance examination requirements. For elementary education programs, 54 percent of public institutions require entrance examinations, compared with 44 percent of private institutions, for secondary education programs, the figures are 52 percent and 44 percent, respectively.

To improve the quality of students majoring in education, some institutions have raised their required entry grade point average (GPA). By 1985, more than 100 institutions raised their GPA requirements from around 2.2 or 2.3 (on a 4-point scale) to a minimum of 2.5 to 2.9. Furthermore, a 1983 survey found that about 85 percent of teacher training programs have revised their curricula in the 5 years prior to the survey.[29] (See figure 1-12.) Another survey showed that since 1980, the average number of credit hours required in education courses had increased.[30] Another quality-related theme is to require less courses in education, and more in substantive subject matter areas. In elementary programs, the percentage of institutions increasing their requirements is highest for computer science (28 percent), mathematics (20 percent), science (17 percent), and communications (16 percent). Fewer institutions increased similar requirements for secondary programs. (See figure 1-13.)

Figure 1-13.
**Percent of U.S. higher education institutions which increased their requirements for selected disciplines in elementary-school and secondary-school teacher education between 1980/81 and 1984/85**




SOURCE: Surveys conducted by the Education Commission of the States, Council on Education, reported in Paul T. Brinkman and Dennis P. Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986)

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### Federal and Private Sector Programs

Other groups are also involved in efforts to improve the quantity and quality of K-12 teachers. These groups include teacher associations, local school districts, Federal agencies, and special commissions and task forces.

Teacher associations have worked to increase teacher benefits and to develop new means for quality control,

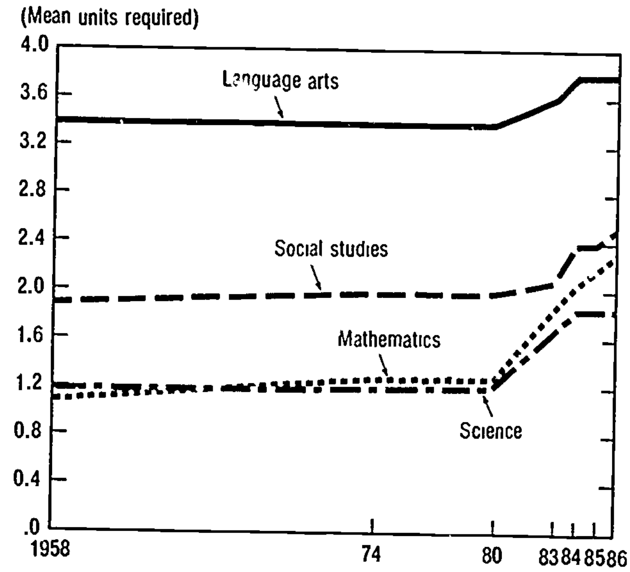
[27]Holmstrom (1985).
[28]Brinkman and Jones (1986), p. 12.
[29]Ibid.
[30]National Center for Education Statistics (1985).

such as a national certification standard. School districts directly influence the demand for teachers and can affect supply, usually by adjusting benefits or changing job requirements.

Federal agencies support various programs aimed at teacher preparation and enhancement. For example, in fiscal year 1987, the National Science Foundation (NSF) allocated nearly $50 million to programs to improve science and mathematics teaching and learning. This funding provided support for developing new materials and model programs to improve undergraduate student teacher preparation and for effective continuing education for working teachers throughout their careers. NSF also supports seminars, conferences, research participation opportunities, and workshops to expand the scientific and mathematics knowledge base of teachers who will take local leadership roles in in-service training of their peers. Other NSF programs help local and regional communities provide both continuing education for teachers who lack the mathematics and science background for the courses they teach, and national recognition for distinguished science and mathematics teachers.[31]

The Department of Energy, through its Lawrence Berkeley Laboratory (LBL), supports several programs to promote the benefits of direct association with science and technology to teachers and students in secondary education.[32] These programs include opportunities for student and teacher interaction in research conducted at LBL, and summer research positions for teachers at national laboratories.

Figure 1-14.
**State-required Carnegie units[1] for high school graduation by subject**




[1]A Carnegie unit is a one-year course in the given subject.
See appendix table 1-25. Science & Engineering Indicators — 1987

## STUDENT REFORM MOVEMENTS

In 1985, 46 States required a minimum number of units for high school graduation. Of these, 39 States had increased their requirements between 1980 and 1985. After 20 years of stability, there have been sharp increases since 1980 in the number of 1-year courses ("Carnegie units") in mathematics and science required by States for high school graduation. (See figure 1-14.) For example, in 1958, 31 States required at least 1.1 year-long mathematics courses in order to graduate from high school; in 1986, 45 States required at least 2.3 units. (See appendix table 1-25.) Science requirements increased from 31 States requiring 1.2 units in 1958 to 45 States requiring 1.9 year-long courses in 1986. There were smaller increases in the requirements for social studies and language arts.

Twenty-two States now require that students pass a minimum competency test before awarding them a high school diploma. In some States, local schools have the option of setting their own standards for these tests, or—in certain cases where the State sets the standards—local schools have the option not to use examination results for grade promotion or graduation. (See appendix table 1-26.)

By 1985, 40 States had taken either legislative or State board action to require or permit schools to identify minimum basic skills that students should acquire. Policies differ widely concerning the grade levels and subjects involved.

## RESEARCH ON TEACHERS AND TEACHING

A large volume of research evidence indicates that teachers play a highly significant role—far greater than those of selected committees, district supervisors, principals, or superintendents—in determining what takes place in the classroom. Not only do teachers make the ultimate decision about what they teach, they also rely heavily on the advice of other teachers as sources of information about new developments.[33]

Teachers also appear to be the primary decisionmakers in selecting and using curricular materials.[34] While this does not mean that all teachers make the ultimate decision about the in-classroom materials (such decisions are often made by school or State board committees), most teachers do, however, have autonomy in the way they utilize these materials and teach their subject matter. This autonomy apparently encompasses teaching style, presentation mode, test selection, grade assignment, and—within the limits set by administrators—determining such activities as out-of-school field trips.

There is also evidence that teachers make a difference in what students learn in the classroom. This finding

[31]NSF (1987).
[32]Otto (1986).
[33]Weiss (1978).
[34]Ibid.

comes from studies showing clearly that children who spend the year in different schools—and even in different classrooms within the same school—learn different amounts during the school year.[35] While these studies do not by themselves demonstrate that differences among teachers explain why more learning takes place in one classroom than another, it can be inferred that teachers are an important factor in explaining such differences.[36]

### Input-Output Studies

Another more challenging area of research tries to link teacher characteristics and student learning. Variables presumed to be indicative of teachers' competence—for instance, years of education, recentness of educational enrichment, years of teaching experience, academic ability, etc.— have been analyzed for their relevance to student learning. The results have been equivocal. Early studies of teachers' intelligence (usually measured by IQ) and its relation to student achievement have concluded that there is no such relationship.[37] The lack of effect of IQ could be because of negligible variability among teachers in this measure or because of IQ's tenuous relationship to actual performance.[38] Other studies have found that teachers' verbal ability is related to student achievement.[39] Verbal ability, rather than intelligence, may be a more sensitive measure of how well teachers can convey ideas and concepts.

Some studies have tried to relate the extent to which student achievement gains can be explained by teachers' demographic characteristics—e.g., teachers' education test scores and teaching experience. There are a few relatively consistent findings. For example, teachers with at least 3 to 5 years of experience are more effective on average than beginning teachers.[40] The dominant conclusion from such research, however, is that most variables used to depict teachers—gender, race, possession of a master's degree, undergraduate major in education—are not consistently related to teaching effectiveness as measured by student test score gains on standardized reading and mathematics achievement tests.[41]

### Process-Product Studies

Another body of research has examined whether specific actions of teachers are systematically related to teaching effectiveness. These studies focus on whether student achievement in a specific subject is positively related to the amount of in-class time devoted to instruction in the subject, as well as how effectively class time is used. There is evidence, for example, that an increased exposure to mathematics may be particularly beneficial to the lowest-achieving mathematics students.[42] Elementary school teachers tend not to take many science and mathematics courses in college, this lack of interest/experience is reflected in classroom performance, where studies have shown that some second-grade teachers averaged only 15 minutes a day on mathematics instruction, while others spent up to 50 minutes a day.[43]

A recent National Academy of Sciences report summarizes the current state of research on teachers and concludes that:

> ...neither input-output studies nor process-product studies provide sure guidance for the development of indicators of the quality of the mathematics and science instruction in school. In one sense this is discouraging, because it makes the task of developing reliable indicators of teaching effectiveness more difficult. In a different sense, however, the results are encouraging, because they underline the fact that effective teachers cannot be defined merely as individuals with specific demographic characteristics who have earned particular academic degrees, or as people who have been trained to behave in predictable routinized ways in the classroom. Such definitions obscure the characteristics that effective teachers have in common with the skills and attitudes of professionals.[44]

## ELEMENTARY AND SECONDARY MATHEMATICS CURRICULA

To understand and evaluate the tested mathematics achievement of U.S. students, the curricula they study—i.e., their opportunities to learn—must be examined. Substantial new findings on this aspect of education are available from the 1981-82 Second International Mathematics Study, covering schools in 20 countries around the world (only 15 countries participated in the eighth grade study). The study obtained detailed information on the content of intended mathematics curricula, what mathematics was actually taught, and how that mathematics was taught.[45] Achievement and attitudes were assessed using internationally developed tests and questionnaires. An important aspect of this study was obtaining reports from teachers as to whether the mathematics on test items had been taught during the year or prior to that year. The resulting data, called "opportunity to learn," provided useful information in interpreting achievement scores among countries.

Internationally, the opportunity-to-learn data correspond closely to the achievement data, as would be expected. For example, in Japan, opportunity-to-learn ratings are among the highest of any country; in the U.S.,

[35]Hanushek (1972).
[36]National Academy of Sciences.
[37]Soar, et al. (1983), pp. 239-246.
[38]Murnane (1985).
[39]Summers and Wolfe (1975).
[40]Penrick and Yager (1983), pp. 621-623.
[41]National Academy of Sciences.
[42]Stallings (1976), pp. 43-47.
[43]Galambos (1985).
[44]National Academy of Sciences.
[45]International Association for the Evaluation of Education Achievement (1987), p. 4.

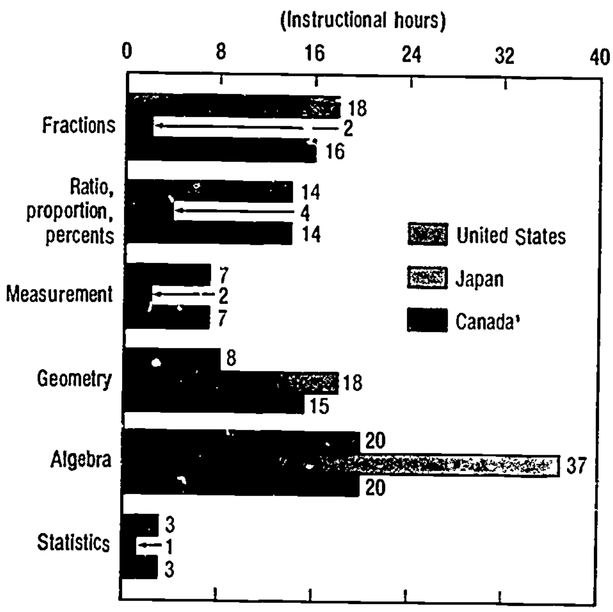
on the other hand, these ratings are about at the international average, or in some cases lower. (See appendix tables 1-27, 1-28, 1-29, and 1-30.)

### Eighth Grade

For comparative purposes, the following sections analyze the mathematics curriculum of the U.S. with Canada (British Columbia), which closely resembles the U.S. educational system, and Japan, whose students traditionally are among the highest scorers on international achievement tests. Thus, the profile of mathematics in the U.S. eighth grade curriculum resembles that of Canada quite closely, but differs markedly from that of Japan. Figure 1-15 shows that the U.S. and Canadian courses distribute their subtopics more evenly than do the Japanese, where most of the eighth grade concentration is on algebra and geometry. This may explain why the Japanese eighth graders performed so well, ranking first among the countries. (See table 1-2.)

In general, the test performances of U.S. students ranked in the bottom one-half of all 20 countries studied. As compared to a 1972 international assessment of eighth grade students, the 1981-82 results were very similar, with a slight improvement in arithmetic (up 6 percent) and a slight decline in geometry (down 6 percent).[16] At the higher cognitive levels, 1981-82 students declined slightly as compared to 1972 students.[17]

Figure 1-15.
**Average instructional hours taught in eighth grade mathematics in the United States, Japan, and Canada, by topic: 1981/82**




¹British Columbia

SOURCE: International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum. Assessing U.S. School Mathematics from an International Perspective*, National Report on the Second International Mathematics Study. University of Illinois (Stipes Publishing Company, January 1987)

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**Table 1-2. Rank order of student achievements on eighth-grade[1] mathematics test for the United States, Japan, and Canada, by curricular subject: 1981/82**

| Subject | United States | Japan | Canada |
|---|---|---|---|
| Arithmetic | 10 | 1 | 3 |
| Algebra | 12 | 1 | 7 |
| Statistics | 8 | 1 | 3 |
| Measurement | 18 | 1 | 8 |
| Geometry | 16 | 1 | 12 |

¹ Japanese students were tested in the seventh grade.

Note: The above rankings are based on the 20-country Second International Mathematics Study.

SOURCE: Travers, K J., *Second Study of Mathematics, Detailed National Report— United States*, Stipes Publishing Company (December, 1986), pp. 167-68

Science & Engineering Indicators—1987

It was found that the U.S. eighth grade mathematics curriculum is more like those at the end of elementary school (approximately sixth grade) elsewhere in the countries studied. But it should also be noted that the U.S. eighth grade mathematics curriculum varies more than is the case in other countries because of U.S. State and local control of schools.[18]

Among the factors identified as causes of deficiency in U.S. student achievement are: the amount of time allocated for instruction, size of classes, comprehensive nature of U.S. public schooling, preparation and status of teachers, and soundness of the teaching provided.[19] However, U.S. analysts involved in the international assessment warn against singling out any one of these factors as "the villain." For example, the U.S. curriculum offers 141 hours of mathematics instruction per year—compared with 132 hours for Canada and 101 hours for Japan. Further, although Japanese students attend school 243 days per year— compared with 180 days in the U.S.— there was generally a lack of systematic relationship between length of school year in days and achievement among the 20 countries in the international assessment.[20]

### Twelfth Grade

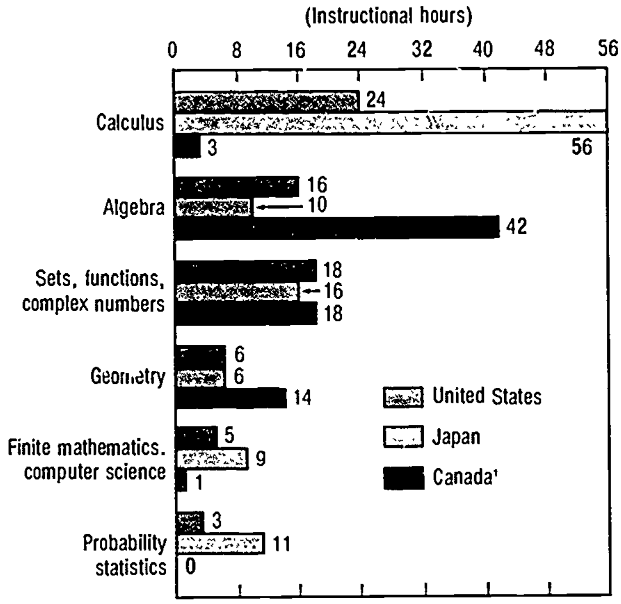
The curricular patterns were more varied among the countries studied at the 12th grade level than at the 8th grade. While the U.S. curriculum was spread rather evenly across algebra, sets/functions, and complex numbers (offered for a total of 58 hours), the Japanese (with a total of 108 hours) have the greatest relative and absolute concentration on calculus. (See figure 1-16.) Japanese students receive twice as much calculus as U.S. students,

[16]Travers (1986), pp. 163-167.

[17]Ibid., p. 161.
[18]Ibid., p. 159.
[19]Ibid., p. 51.
[20]Ibid., p. 52.

Figure 1-16.

**Average instructional hours taught in twelfth grade mathematics in the United States, Japan, and Canada, by topic: 1981/82**




¹British Columbia

SOURCE: International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum Assessing U.S School Mathematics from an International Perspective*. National Report on the Second International Mathematics Study. University of Illinois (Stipes Publishing Company, January 1987)

Science & Engineering Indicators — 1987

**Table 1-3. Rank order of student achievements on 12th-grade mathematics test for the United States, Japan, and Canada,[1] by curricular subject: 1981**

| Subject | United States | Japan | Canada |
|---|---|---|---|
| Sets and relations .......... | 10 | 2 | 14 |
| Number systems ........... | 12 | 2 | 11 |
| Geometry ................. | 12 | 2 | 14 |
| Algebra ................... | 14 | 2 | 12 |
| Probability and statistics ..... | 12 | 2 | 13 |
| Elementary functions and calculus ............. | 12 | 2 | 15 |

[1] British Columbia.

Note: The above rankings are based on the 15-country Second International Mathematics Study.

SOURCE: Travers, K.J., *Second Study of Mathematics, Detailed National Report — United States*, Stipes Publishing Company (December, 1986), pp. 359-362

Science & Engineering Indicators—1987

and as much as U.S. students receive for all other subtopics combined. The Canadian concentration is on algebra. Only one-fifth of the U.S. students taking these advanced courses receive Advanced Placement (AP) calculus whereas most of the Japanese students do. Thus, 4 to 5 times more Japanese than U.S. students take AP calculus.

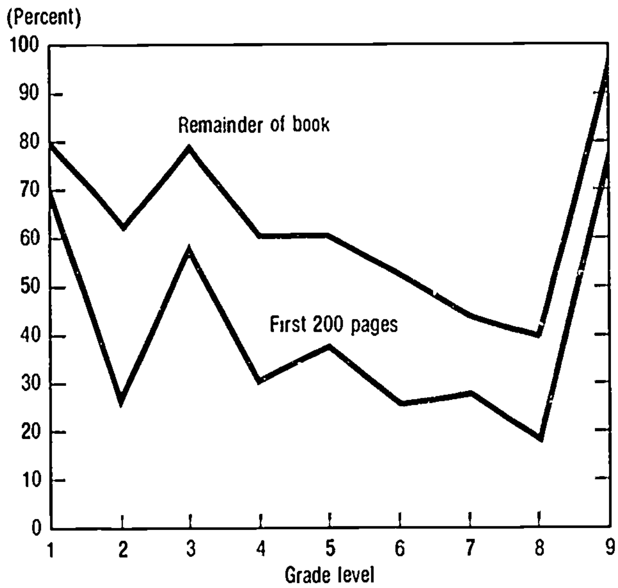
With these considerations in mind, it is no surprise that Japanese 12th grade mathematics students do so well in comparison with those from the U.S. and Canada. (See table 1-3.) Japanese schools retain 92 percent of their 17-year-old students, compared to 82 percent for the United States and Canada, which further heightens these contrasts.[51] It is interesting to note that Canada and the U.S. each outrank the other in performance in the two curricular areas to which they devote the greater number of hours of instruction.

### Textbook Content

In addition to the opportunity to learn data, a recent study[52] investigated how much of the content is "new" in three K-8 mathematics textbook series and the algebra books published by the same companies. Content was defined as "new" in a cumulative sense—a topic was new in a fourth grade text, for example, if it had not appeared in any of the K-8 texts of the series. The study found that a generally low percentage of new content is clearly evident. (See figure 1-17.) First, there is a plunge in percentage of new content between first and second grade math

Figure 1-17.

**Average percent new content in three mathematics text series, the first 200 pages and the remainder of the book**




See appendix table 1-31

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[51] Travers and Kifer (1986), p. 10.
[52] Flanders (1986).

texts; the average percentage then declines rather steadily from fifth through eighth grade. Finally, there is a huge jump in the percentage of new content between eighth and ninth grade texts as algebra is introduced into the curriculum.

The study also analyzed the new pages of content when each book is split at page 200. For grades 1-3, this is about two-thirds of the way through the text; for grades 4-8, it is approximately the halfway point. For the algebra texts, it is again about two-thirds of the way through. The study found, as expected, that most new content in any mathematics text is concentrated after page 200. In grades 7-8, for example, less than 28 percent of the first half of the books contain new material.

In its conclusions, the study noted that the percent of new content is very low (49 percent or less) in all mathematics texts beyond the third grade; the seventh and eighth grade texts have the least (33 percent). This last ratio seems particularly low when compared with the approximately 90-percent new content of algebra books in the ninth grade. New content is covered primarily at the latter part of the school year; furthermore, not all teachers cover all chapters in the latter parts of the texts.

The authors summarize their findings as follows:

> There should be little wonder why good students get bored— they do the same thing year after year. Average or slower students get the same message, and who could blame them for becoming complacent about their math studies? They know that if they don't learn it now it will be retaught next year. Then students encounter an algebra course. The pace picks up (there are about 100 more pages in an algebra book than an eighth grade text), the new content comes at them at an 88-percent level (over 4 days per week they face new content), and the old content is usually presented with a new degree of formalism that clouds the fact that it is just review.[53]

### Student Attitudes toward Mathematics

The attitudes of students toward mathematics determine in part their success in mathematics and their interest in mathematically related careers. The attitudes of 12th graders in the Second International Mathematics Study were generally more favorable than those of the 8th graders. This may be because of greater familiarity with the subjects and the fact that by the 12th grade, a greater proportion of the more able students are taking mathematics. For example, 85 percent of the 12th grade mathematics students felt that the subject helps one think logically; this belief was shared by only 64 percent of the 8th graders. The older students were less likely to believe that there is always a rule to follow in mathematics—67 percent versus 82 percent. (See appendix table 1-32.)

Overall, the attitudes of U.S. students tended to be positive, contrasting sharply with those of the Japanese students who had rather negative attitudes toward the subject and found the mathematics class an unpleasant place to be.[54]

Two-thirds of the eighth grade U.S. mathematics students thought the subject to be of high importance; 55 percent found it easy, but only 40 percent liked it. (See appendix table 1-33.) Very similar overall ratings were given by 12th graders to the importance, difficulty, and interest in mathematics. (See appendix table 1-34.) Further, attitudes toward curricular subtopics varied widely in both grade levels. The most liked item in both grade levels was "calculators." In both grades, there was strong evidence of a desire to do well in mathematics, that mathematics is generally learnable, and that assigning more mathematics would not be widely resisted. As would be expected for students who have elected to take advanced mathematics, 12th grade students were more positive. (See appendix table 1-32.)

There was little support for a view of mathematics as primarily a male subject or career opportunity. Less than 20 percent of the students at both levels believed that men make better scientists and engineers, or that boys need to know more mathematics than girls, or that boys have more natural ability in mathematics than do girls.[55]

[53]Ibid., p. 7.

[54]Travers and Kifer (1986), p. 35.
[55]Travers (1986), p. 387.

## REFERENCES


Akin, J.N., *Tenth Annual Teacher Supply/Demand Report* (Madison, WI: Association for School, College and University Staffing, 1986).

Brinkman, P.T. and D. Jones, "State and Institutional Initiatives to Increase the Quantity and Quality of K-12 Science and Mathematics Teachers" (Boulder, CO: National Center for Higher Education Management Systems, 1986).

Darling-Hammond, L., A.E. Wise, and B. Berry, *Effective Teacher Selection from Recruitment to Retention* (Santa Monica, CA: Rand Corporation, 1987).

Davis, J., *The Effect of Mathematics Course Enrollment on Racial/Ethnic Differences in Secondary School Mathematics Achievement* (Educational Testing Service, 1986).

Education Commission of the States, *50-State Survey of State Incentives for Attracting Science and Mathematics Teachers* (Denver: 1984).

Flanders, J., "How Much of the Content in Mathematics Textbooks is New?," unpublished paper, 1986.

Galambos, E.C., *Teacher Preparation: The Anatomy of a College Degree* (Atlanta: Southern Regional Education Board, 1985).

Hanushek, E., *Education and Race* (Lexington, MA: Heath-Lexington, 1972).

Holmstrom, E.I., *Quality in Teacher Education Programs* (Washington, DC: American Council on Education, 1985).

International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum* (Champaign, IL: Stipes Publishing Co., 1987).

Johnston, K.L. and B.G. Aldridge, "The Crisis in Science Education: What Is It? How Can We Respond?," *Journal of College Science Teaching* (September/October 1984).

Lanier, J., "Research on Teacher Education," Occasional Paper No. 80 (Institute for Research on Teaching, Michigan State University, 1984).

Murnane, R.J., "Do Effective Teachers Have Common Characteristics?: Interpreting the Quantitative Research Evidence," paper presented at the National Research Council Conference on Teacher Quality in Science and Mathematics, Washington, DC, June 1985.

Murnane, R.J. and R.J. Olsen, "The Career Paths of Michigan School Teachers," paper presented to the American Educational Research Association, Washington, DC, April 1987.

National Academy of Sciences, *Improved Indicators of Science and Mathematics Education in Grades 1-12*, unpublished document.

National Center for Education Statistics, Planning Group on Teaching and Teachers, *New Initiatives: The Teaching and Teachers Program* (Washington, DC: Government Printing Office, 1985).

National Center for Education Statistics, *The Condition of Education: 1987 Edition* (Washington, DC: Government Printing Office, 1987).

National Commission for Excellence in Teacher Education, *Call for Change in Teacher Education* (Washington, DC. American Association of Colleges for Teacher Education, 1985).

National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1986).

National Science Foundation, *Teacher Preparation and Enhancement, Program Announcement and Guide*, NSF 87-10 (Washington, DC: NSF, 1987).

Otto, R., "The Laboratory. A Link Between Research and Precollege Education," *LBL Research Review* (Summer 1986).

Penrick, J.E. and R.E. Yager, "The Search for Excellence in Science Education," *Phi Delta Kappan*, 64(8) (1983).

Research Triangle Institute, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1986).

Rosenholtz, S.J., "Effective Schools: Interpreting the Evidence," *American Journal of Education*, 93 (1984).

Rumberger, R., "Is There Really a Shortage of Mathematics and Science Teachers: A Review of the Evidence," Report No. 84-A26 (Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University, 1984).

Soar, R.S., D.M. Medley, and H. Coker, "Teacher Evaluation: A Critique of Currently Used Methods," *Phi Delta Kappan*, 65(4) (1983).

Stallings, J., "How Instructional Processes Relate to Child Outcomes in a National Study of Follow Through," *Journal of Teacher Education*, 27 (1976).

Summers, A.A. and B.L. Wolfe, *Equality of Educational Opportunity Quantified: A Production Function Approach* (Department of Research, Federal Reserve Bank of Philadelphia, 1975).

Sykes, G., "Public Policy and the Problem of Teacher Quality: The Need for Screens and Magnets," in L.S. Shulman and G. Sykes (eds.), *Handbook of Teaching and Policy* (New York: Longman, Inc., 1983).

Task Force on Teaching as a Profession, *A Nation Prepared. Teachers for the 21st Century* (New York. Carnegie Forum on Education and the Economy, 1986).

Travers, K.J., *Second Study of Mathematics, Detailed National Report—United States* (Champaign, IL. Stipes Publishing Co., 1986).

Travers, K.J. and E. Kifer, *Opportunities to Learn Mathematics in U.S. Classrooms*, unpublished report, 1986.

U.S. Congress, House Committee on Science and Technology, Subcommittee on Science, "Symposium on Minorities and Women in Science and Technology," statements by Dr. Robert Suzuki (Washington, DC. Government Printing Office, 1982).

U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States. 1983 and 1973 Editions* (Washington, DC. Government Printing Office).

Vance, V.S. and P.C. Schlechty, "The Distribution of Academic Ability in the Teaching Force: Policy Implications," *Phi Delta Kappan*, 64 (1982).

Vetter, B.M., *Attitudes, Participation, and Achievement of Women and Minorities in Pre-college Science and Math Education*, unpublished document, 1986.

Weiss, I.R., *Report of the 1977 National Survey of Science, Mathematics and Social Science Education* (Research Triangle Park, NC: Research Triangle Institute, 1978).

Weiss, I.R., *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987).

# Chapter 2
# Higher Education for Scientists and Engineers

# Higher Education for Scientists and Engineers

## HIGHLIGHTS

- *Full-time undergraduate engineering enrollments decreased from 406,000 to 370,000 between 1983 and 1986.* In contrast, however, full-time grad ate enrollments in engineering increased between 1983 and 1986 from 55,000 to 62,000. This increase is largely explained by the growth in foreign student enrollments. (See pp. 41-44.)
- *Foreign graduate students represented 20 percent of all science and engineering (S/E) graduate students in 1986.* They have increased their enrollments at an average annual rate of 6.9 percent since 1980, compared with a rate of 0.5 percent for U.S. citizens. (See p. 44.)
- *Part-time enrollments in all graduate S/E programs increased by 3.7 percent from 1980 to 1986, compared with a growth in full-time enrollments of 1.9 percent.* This difference is even greater in master's degree-granting institutions than in doctorate-granting schools. Full-time enrollment growth at master's-granting institutions between 1980 and 1986 was negligible, while part-time enrollments at these schools increased at an average annual rate of 5.6 percent. Thirty-one percent of graduate enrollments in master's degree-granting institutions were full-time in 1986, compared with 68 percent in doctorate-granting institutions. (See pp. 42-43.)
- *Between 1984 and 1985, full-time enrollments of black U.S. citizens in graduate S/E programs declined 6 percent (from 7,632 to 7,272), and remained unchanged in 1986.* Part-time enrollments of blacks decreased from 7,295 to 7,119 from 1985 to 1986. (See pp. 43-44.)
- *S/E Ph.D.'s continue to increase but remain below the peak years of 1972 and 1973.* These increases are wholly accounted for by foreign citizens. (See pp. 44-45.)
- *Since 1983, about 25 percent of all S/E doctorates have been awarded to women.* Women earned 38 percent of S/E baccalaureates and 30 percent of S/E master's degrees in 1985. These ratios are considerably higher than those of just 10 years ago. (See p. 45.)
- *The employment of doctoral scientists and engineers in academia increased at 3 percent to 4 percent per year between 1977 and 1985.* The employment of doctoral engineers increased at 4 percent per year; employment of doctoral scientists increased at 3 percent per year. (See pp. 48-49.)
- *U.S. academic faculties continue to age except in engineering.* In the sciences, the proportion of doctoral scientists younger than 40 years decreased from 33.8 percent to 32.2 percent from 1983 to 1985. By contrast, in engineering, the proportion of doctoral scientists younger than 40 increased between 1983 to 1985 from 28.2 percent to 29.8 percent. (See pp. 48-49.)
- *Most S/E Ph.D.'s earned their baccalaureates at research-intensive and other doctorate-granting institutions.* Proportions of S/E Ph.D.'s earning their baccalaureates at research-intensive universities have declined over the decades, reflecting the growth of comprehensive and other doctorate-granting schools. Baccalaureate origins differ by gender, racial/ethnic group, and field. In addition, a small number of selective small schools produce relatively large percentages of their baccalaureates who go on to obtain the Ph.D. (See pp. 47-48.)

In the past few years, the Nation has become increasingly aware of the significance of an educated population—especially in science and engineering (S/E)—in influencing U.S. international economic competitiveness. This chapter therefore focuses on four major sets of indicators of higher education in science and engineering:

- U.S. enrollments in S/E higher education,
- S/E degrees awarded;
- Student support patterns, and
- Information on institutions and faculty in S/E higher education.

This chapter also discusses several other trends in S/E higher education of concern to policymakers. One of these is the decreasing size of the traditional college-going population in the United States. Other trends of interest include. the rates at which women choose to study science and engineering, participation in S/E higher education of underrepresented minority groups; the degree to which the U.S. higher educational system is becoming "internationalized" as it attracts increasing numbers of foreign students in S/E fields; and trends toward part-time study, often by older-than-average students, and in contrast to declines in the number of students pursuing full-time S/E studies.

The chapter also provides data on the undergraduate institutions of S/E Ph.D. earners.

## ENROLLMENTS

This section presents indicators of S/E enrollments for both undergraduates and graduates, covering college enrollment rates of different population groups; recent trends in enrollment patterns which have helped offset declines in the normal college-age population; and important differences in S/E field enrollments which will influence the mix of degrees awarded to these students as they complete their studies and enter the job market or graduate schools.

### Undergraduate Enrollments

Indicators of participation in undergraduate education are restricted to aggregate trends in college-going rates of various age, ethnic, and gender groups.[1] These gross indicators, when observed over time,[2] suggest the value placed on and access to higher education by these various groups and how these evaluations may be changing as shown by changing rates of college attendance.

Figure O-18 in the Overview shows the college-going rates for U.S. 18- to 21-year-olds. Throughout the 1970's and 1980's, about one-third of the total U.S. population in these age groups were enrolled in institutions of higher education. (See appendix table 2-1.) During the past 5 years. the college-going rates for some groups in the population have increased by 5 to 6 percentage points. These increases—especially those for women—have kept total undergraduate enrollments sufficiently high to compensate for the decline in size of the 18-year-old population, which began in 1979. According to the Census of Population, total college enrollments (all institutions, both genders, all races) have remained virtually unchanged for 3 years.

### 1985 Freshmen

Two specialized sources of indicators show the intentions of freshmen to major in certain fields. One of these sources is an annual survey of engineering and engineering technology programs conducted by the Engineering Manpower Commission of the American Association of Engineering Societies. The other is a national study of freshmen conducted each fall by the Cooperative Institutional Research Program at the University of California, Los Angeles (UCLA).

*Engineering and Technology Enrollments.* Each fall, the Engineering Manpower Commission surveys U.S. engineering and engineering technology programs to estimate program enrollments.[3] These specialized data—while not strictly comparable to the other data in this chapter—are indicators of trends in undergraduate intentions to obtain a degree in engineering, either at the bachelor's or 5-year level, or at the associate or 2-year level.[4]

Total full-time enrollments in engineering programs decreased between 1983 and 1986 at an average annual rate of -3.1 percent. (See table 2-1.) The overall pattern showed significant growth from 1979 to 1982, a leveling off in 1983, and declines in 1984, 1985, and 1986. Part-time enrollments, in contrast, continued to increase by an average of 2.9 percent per year since 1983. Part-time students constitute 9 percent of all enrollments.

Enrollments in engineering technology programs—which provide specialized skills for performing technical tasks at a sub-professional level—have increased for both full- and part-time students by an annual average of 7.6 percent from 1979 to 1985. However, all engineering technology enrollments declined from 1983 to 1985. A growing number of full-time engineering technology students continue past the associate degree level to work on their bachelor of engineering technology degree; these enrollments increased by an average annual rate of 14.5 percent between 1979 and 1985.

*Freshmen Characteristics.*[5] The most recent survey of freshmen in institutions of all types shows that the 1986 freshmen expect to study longer and earn higher degrees than did freshmen 5 years previously. (See figure O-19 in Overview.) For example, freshmen who intend to obtain Ph.D.'s (in all fields) increased from 8.2 percent in 1982 to 9.7 percent in 1986; similar increases were reported in the relative percentages of entering freshmen hoping to attain bachelor's or master's degrees. (See table 2-2.)

Freshmen in 1986 were less likely to be planning a major in an S/E field than was the case in 1982. One of the more notable decreases was in the number of freshmen planning to major in computer science, down from 4.4 percent in 1982 to 1.9 percent in 1986. Engineering, too, decreased as a planned major, dropping from 12.6 percent in 1982 to 10.9 percent in 1986.

Indicators of these freshmen's career objectives also reflect these choices of major. The percent of entering freshmen planning careers as computer programmers or analysts dropped by more than one-half from 1982 to 1986. Engineering also declined for this period as a career of choice.

### Graduate Enrollments

Total graduate student enrollment in science and engineering fields in all institutions increased at an average

[1]A special survey of engineering and technology enrollments is discussed below.

[2]The Bureau of the Census' Current Population Survey (CPS) is conducted each October. CPS is a survey of approximately 60,000 households, covering about 125,000 people and 8,000 college students. Because the data discussed here are developed from a sample of the population, data on smaller groups of the population should be used with care.

[3]Engineering Manpower Commission (1986).

[4]The data on engineering programs are from 4 and 5 year programs approved by the Accreditation Board of Engineering and Technology. Upon successful completion of these programs, the student receives a bachelor of engineering degree or, in the case of the 5-year programs, an "engineering professional degree." The engineering technology enrollments, in contrast, are usually 2-year programs terminating in an associate degree, but some of these programs also include 4-year study.

[5]All of the data discussed in this section are from *The American Freshman. National Norms For Fall 1982, 1983, 1984, 1985, and 1986* by the Cooperative Institutional Research Program, UCLA. Excluded from the survey are part-time freshmen and students who have previously attended college for credit. Also excluded are semi-professional and proprietary schools, as well as some very small schools. For a complete description of survey methodology, see any of the UCLA volumes.

## Table 2-1. Undergraduate enrollment in engineering and engineering technology programs

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986[1] |
|---|---|---|---|---|---|---|---|---|
| | Engineering programs | | | | | | | |
| Total full-time | 340,488 | 365,117 | 387,577 | 403,390 | 406,144 | 394,635 | 384,191 | 369,520 |
| Freshmen | 103,724 | 110.149 | 115,230 | 115,303 | 109,638 | 105,249 | 103,225 | 99,238 |
| Sophomore | 78,594 | 84,982 | 87,519 | 89,785 | 89,515 | 83,946 | 79,627 | 76,195 |
| Junior | 74,928 | 80,024 | 86,633 | 90,541 | 91,233 | 89,509 | 84,875 | 80,386 |
| Senior | 77,823 | 84,442 | 92,414 | 102,055 | 109,036 | 109,695 | 110,305 | 107,773 |
| Fifth year | 5,419 | 5,520 | 5,731 | 5,706 | 6,722 | 6,236 | 6,1[illegible]9 | 5,928 |
| Total part-time | 25,811 | 32,227 | 32,825 | 31,940 | 35,061 | 34,864 | 36,673 | 38,137 |
| | Engineering technology programs | | | | | | | |
| Total full-time | 38,347 | 47,755 | 48,847 | 37,198 | 60,096 | 48,218 | 49,210 | NA |
| First year | 18,102 | 22,127 | 21,483 | 14,123 | 23,995 | 17,030 | 18,098 | NA |
| Second year | 10,985 | 13,302 | 14,434 | 11,505 | 16.828 | 13,856 | 13.590 | NA |
| Other full-time associates | 455 | 784 | 541 | 221 | 709 | 785 | 344 | NA |
| Bachelor of engineering technology | | | | | | | | |
| Third and later years | 8,805 | 11,542 | 12,389 | 11,349 | 18,719 | 16,686 | 17,178 | NA |
| Total part-time | 15,271 | 17,395 | 16,639 | [illegible] | 24,134 | [illegible]1,341 | 18,781 | NA |

[1] Preliminary.

Note: NA = Not available.

SOURCE: Engineering Manpower Commission, *Engineering and Technology Enrollments, Fall 1935*, Part I (p. vi) and Part II (p. v). 1986, and unpublished tabulations.

Science & Engineering Indicators—1987

## Table 2-2. Freshmen plans

| | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|
| | Percent | | | | |
| Highest degree planned: | | | | | |
| Ph.D or Ed. D. | 8.2 | 8.5 | 9.2 | 9.2 | 9.7 |
| Master's | 30.5 | 30.4 | 31.2 | 31.6 | 33.0 |
| B.A. or B.S. | 38.3 | 36.5 | 37.6 | 38.2 | 36.8 |
| Probable major: | | | | | |
| Biological sciences | 3.7 | 3.8 | 4.2 | 3.4 | 3.9 |
| Engineering | 12.6 | 11.7 | 11.0 | 10.7 | 10.9 |
| Physical sciences | 2.5 | 2.5 | 2.6 | 2.4 | 2.4 |
| Social sciences | 5.8 | 6.1 | 6.7 | 7.6 | 8.0 |
| Computer sciences | 4.4 | 4.5 | 3.4 | 2.3 | 1.9 |
| Business | 24.2 | 24.4 | 26.4 | 26.8 | 26.9 |
| Education | 6.0 | 6.0 | 6.5 | 7.1 | 8.1 |
| Arts and humanities | 8.2 | 7.9 | 7.7 | 8.3 | 9.0 |
| Professions | 13.3 | 14.4 | 14.1 | 12.9 | 11.7 |
| Probable career occupation: | | | | | |
| Computer programmer or analyst | 8.8 | 8.5 | 6.1 | 4.4 | 3.5 |
| Scientific researcher | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 |
| Engineer | 12.0 | 10.8 | 10.4 | 10.0 | 9.7 |

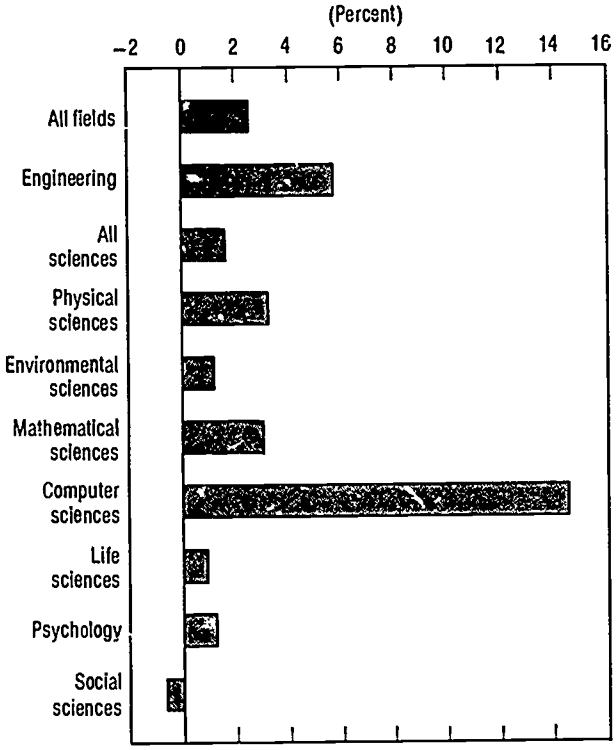
SOURCE: Cooperative Institutional Research Program, *The American Freshman: National Norms for Fall, 1986*, and reports with the same title for 1982-85, University of California at Los Angeles and American Council on Education (December, 1986)

Science & Engineering Indicators—1987

annual rate of 2.6 percent from 1980 to 1986 (see figure 2-1), although full-time U S citizens in doctorate-granting institutions increased only 0.5 percent during this period. (See appendix table 2-3.) Across-field differences in enrollment patterns continued to be considerable, however. For instance, graduate enrollments in computer science led the increases at about 15 percent per year for the past 6 years. Similarly, engineering enrollments continued to grow strongly. Graduate enrollments in the social sciences, on the other hand, declined at an average annual rate of 0.6 percent since 1980. (See appendix table 2-2.)

Graduate enrollment trends also differ when citizenship, institutional level, and student status are taken

Figure 2-1.
**Average annual percentage change in graduate enrollments, by field, 1980-1986**




See appendix table 2-7. Science & Engineering Indicators — 1987

*Postdoctorates.* S/E postdoctorates pursuing advanced study and research in doctorate-granting institutions increased at a rate of 6.8 percent from 1985 to 1986, an increase over the 1980-86 average annual growth rate of 4.6 percent. (See appendix table 2-6.) From 1985 to 1986, growth in postdoctorate appointments was most notable in the environmental sciences (11.5 percent), physical sciences (6.6 percent), and life sciences (7.5 percent).

*Enrollments by Gender.* One of the strongest trends in graduate S/E enrollments during the past decade has been the increasing enrollment rates of women. These increases, coupled with swelling enrollments by foreign nonresidents (see below), have helped offset declines in enrollment stemming from a shrinking population pool of graduate-age students.

Women have increased their matriculation rates in virtually all S/E fields. (See appendix table 2-7.) Average annual female enrollment growth from 1980 to 1986 has been particularly strong in computer science (15.8 percent), engineering and most of its subfields (12.6 percent), and in the physical sciences (7.2 percent). Male enrollment growth in these fields for the same years was 5.0 percent, 14.2 percent, and 2.4 percent, respectively.

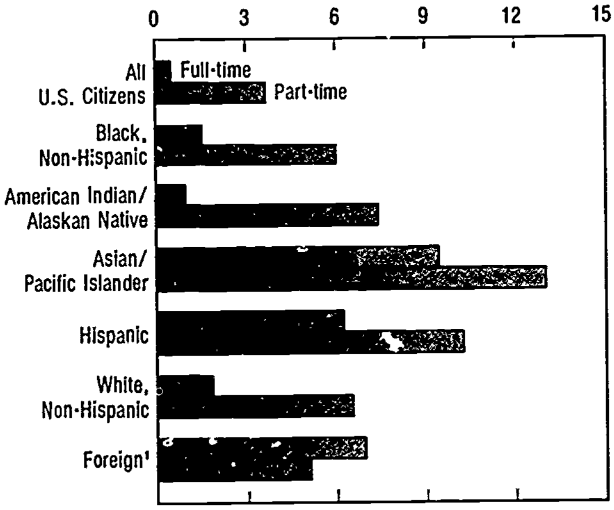
Despite these impressive growth rates, women still participate in S/E graduate education in numbers far below their share of the general population. S/E enrollments in 1986 by gender, for full- and part-time study in all institutional types, show that considerable progress is still needed to achieve equal participation by men and women in U.S. S/E higher education.

*Enrollments by Racial/Ethnic Status.* The overall college-going rates of blacks, Hispanics, Asian-Americans, and

into account. For example, full-time graduate S/E enrollment of U.S. citizens in doctorate-granting institutions increased 1.3 percent in 1986 over 1985, compared to a 6-year trend of 0.5 percent. (See appendix table 2-3.) Foreign citizen enrollments, in contrast, increased 9.7 percent in 1986, compared to a 6-year trend of 6.9 percent. (See appendix table 2-4.) This increase (2.6 percent) in total graduate S/E enrollments was concentrated in doctorate-granting institutions; S/E enrollments in master's degree-granting institutions decreased -1.1 percent. (See appendix table 2-5.)

*Part-Time Graduate Enrollments.* One of the more persistent S/E enrollment trends is the increased tendency to pursue graduate S/E studies on a part-time basis. Full-time S/E graduate enrollment increased in all institutions at an average annual rate of 1.9 percent from 1980 to 1986. (See figure 2-2.) Part-time enrollments, in contrast, increased at a 3.7-percent rate. The trend is stronger in master's degree-granting institutions. Full-time enrollments at these institutions have changed very little since 1980; part-time enrollments in these schools, on the other hand, increased at an average annual rate of 5.6 percent since 1980. In 1986, 68 percent of S/E graduate enrollment in doctorate-granting institutions was full-time, compared with only 31 percent in master's-granting institutions. (See appendix table 2-5.)

Figure 2-2.
**Average annual percentage change in graduate S/E enrollments, by citizenship, racial/ethnic background, and enrollment status, 1980-1986**




[1]Part-time trend is for 1982-1986

See appendix tables 2-2 and 2-7. Science & Engineering Indicators — 1987

Native Americans differ markedly from those of the white population. These rates also differ by gender across racial/ethnic groups. (See figure O-18 in Overview.) Whites (excluding white Hispanics) aged 18-21 have, from 1978 to 1985, slowly increased their enrollments in higher education to near 40 percent for both genders. (White males, however, have still not achieved their enrollment rates of the early 1970's.) Black males are increasing their college enrollment rates while black female college enrollment is holding steady. (See appendix table 2-1.) In 1985, black males and females aged 18-21 attended college at 26 percent and 24 percent, respectively.

Blacks are far less likely than whites to continue their education at the graduate level, and a smaller percentage of them enroll in S/E programs in graduate school. Moreover, full-time enrollment of black U.S. citizens in graduate S/E programs remained unchanged in 1986 over 1985, compared with an increase in white U.S. citizen enrollment of 1.7 percent. Part-time enrollment of blacks decreased in 1986 over the previous year by 2.4 percent. Hispanic U.S. citizens increased full-time enrollments in 1986 by 5.1 percent, but decreased part-time S/E study by -4.4 percent. (See appendix table 2-2.)

Black enrollment patterns differ from white enrollments in several ways. In 1986, blacks were more likely to be enrolled on a part-time basis than whites; 49 percent of black U.S. citizens in all institutions were enrolled on a part-time basis while the equivalent figure for whites was 41 percent. Blacks were less likely than whites to be enrolled in doctorate-granting institutions; blacks also were less likely than whites (10.8 percent versus 19.0 percent) to be enrolled in graduate-level engineering programs. (See appendix tables 2-2 and 2-3.)

One of the more noticeable trends in graduate S/E enrollment has been the strong interest in these fields by U.S. citizens from Asian backgrounds. Total S/E graduate enrollment growth of Asians/Pacific Islanders averaged 13 percent from 1982 to 1986. (See appendix table 2-2.) These students select engineering, computer science, and mathematics at rates higher than any other U.S. racial/ethnic group. Their enrollment rates in engineering equaled those of foreign students in graduate S/E engineering in 1986, and they were more likely than whites to choose engineering (36 percent versus 19 percent).

*Enrollments by Citizenship.* One of the most persistent trends in S/E enrollment patterns at U.S. institutions has been the increasing numbers of non-U.S. citizens. While at the undergraduate level, non-U.S. citizens made up less than 5 percent of the total student population in 1982, on the graduate level—and in S/E fields—the role of foreign students is much more evident.

Foreign students represented 19.8 percent of all S/E graduate students in all institutions in 1986. (See appendix table 2-2.) They were even more heavily represented in doctorate-granting institutions (28 percent) and in at least three fields at these institutions—mathematics, engineering, and computer science—made up about 40 percent of the total graduate enrollment. (See figure O-20 and appendix table 2-4.) Most of these foreign S/E graduate students were studying full-time, this was at least in part because of Immigration and Naturalization Service regulations requiring full-time study by persons on student visas.

Since 1980, full-time S/E graduate enrollments of U.S. citizens in all institutions have increased at an average annual rate of 0.4 percent, while non-U.S. citizen enrollments have increased at an average annual rate of 7.0 percent. This illustrates the extent to which U.S. institutions offering S/E graduate degrees have depended on foreign student enrollment for much of their expansion. Higher education systems in other industrialized countries have also experienced increased enrollments of foreign students. This trend indicates an "internationalization" of the higher education services market, with the industrial countries providing their educational services to citizens from less developed countries. In the U.S. in 1984-85, for example, 12 percent of the foreign students were from Africa, 14 percent from Latin America, 17 percent from the Middle East, and 42 percent from South and East Asia. (See appendix table 2-8.) While the U.S. has the largest number of foreign students among the industrialized nations, it ranks 18th in terms of the proportion of students from foreign countries.[6]

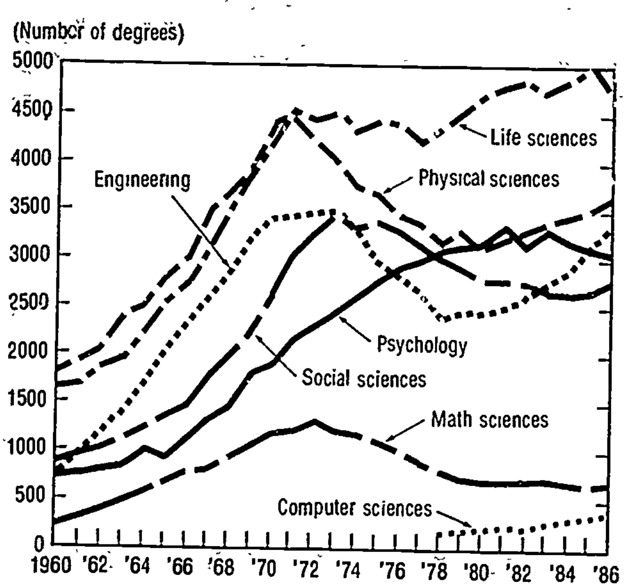
## SCIENCE AND ENGINEERING DEGREES

### Overall Degree Trends

In 1986, 530 more Ph.D.'s in all S/E fields combined were awarded by U.S. educational institutions than in

[6]NSF (1987b), p. 7.

Figure 2-3.
**Science and engineering doctorates**




See appendix table 2-9.

Science & Engineering Indicators — 1987

1985. (See figure 2-3.) This increase was largely accounted for by engineering Ph.D.'s, which increased by 7 percent over 1985; science Ph.D.'s increased by 2 percent. Computer science and the physical sciences led the increases, and mathematical sciences Ph.D.'s were up over the previous year for the first time in 14 years.[7]

While the total number of Ph.D.'s awarded by U.S. institutions in all fields has changed little since 1979, the proportion of those awarded in S/E fields has increased—by about 4 percentage points—to about 59 percent. (See appendix table 2-10.) This ratio of S/E doctorates to all doctorates is, however, below that of approximately 65 percent attained in the early 1960's. And in absolute numbers, both total Ph.D.'s awarded and Ph.D.'s in S/E fields still remain below the peak years of 1973 and 1972, respectively.

Baccalaureate and master's degree awards in S/E fields[8] have also increased over the past few years. At the baccalaureate level, the total number of S/E degrees earned increased in 1979 after 5 years of decline. Master's awards in S/E fields increased beginning in 1981 after a similar period of decline. (See appendix table 2-10.)

In 1984, S/E degrees as a percentage of all baccalaureates attained their peak ratios of the late 1960's (about 32 percent). In contrast, however, master's S/E degrees as a percentage of all master's were 23 percent, far below the 30-percent ratio of the 1960's.

### Time-to-Ph.D.

One of the more persistent trends in S/E higher education is the increasing length of time incurred between the baccalaureate and doctorate degrees.[9] The median number of years between receiving the bachelor's degree and earning the doctorate has increased since 1974 in the physical sciences (by about 6 months), engineering (3 months), life sciences (15 months), and social sciences (24 months). (See appendix table 2-11.)

### Ph.D.'s by Citizenship

The number of U.S. citizens earning doctorates in S/E fields has been declining since at least 1975.[10] In contrast, Ph.D. awards to non-U.S. citizens have increased steadily, these largely account for increases in total Ph.D. output over the past 8 years.

Foreigners study in the U.S. on either permanent resident visas or temporary (student) visas. In 1985, the percentage of total S/E Ph.D.'s awarded to foreign-born students hit an all-time high at 26 percent, with individual field ratios reaching (for example) 55 percent in engineering and 26 percent in the physical sciences.[11]

Most foreign students have temporary visas, and about 50 percent of these plan to stay in the U.S. to work. About 85 percent of those students with permanent visas plan to remain in the U.S.[12] While these *percentages* have not changed in recent years, the *number* of such foreign-born Ph.D. earners planning to remain in the U.S. has increased.

### S/E Degrees by Gender

Female participation in science and engineering, as indicated by S/E degrees awarded to women, has increased steadily over the past 25 years. (See appendix table 2-10.) In 1985, women earned 38 percent of all S/E bachelor's degrees, 30 percent of S/E master's degrees, and 25 percent of S/E Ph.D.'s. These percentages were up from 16 percent, 10 percent, and 7 percent, respectively, in 1960.

In contrast to these impressive increases in percentages of S/E degrees awarded to women at various levels, the declining rates as the level of study increases show that women are less likely than men to continue in S/E study. However, the objective of increasing the rates at which women continue S/E education was clearly achieved through 1986, when women received 26 percent of all S/E Ph.D.'s earned by U.S. citizens, compared with 9 percent in 1970.[13] In recent years, however, increases in the percentage of S/E Ph.D.'s obtained by women have slowed.

## S/E GRADUATE STUDENT SUPPORT

One indicator of the value society places on science and engineering is the financial support provided to students in these fields. Especially at the expensive, higher levels of education, changes in support patterns can reflect society's perception of the need to invest in the higher education of future scientists and engineers.

There are two types of indicators of support for graduate education in science and engineering: (1) reports from students and institutions about the main sources of support for graduate study, and (2) reports from Federal

[7] The discussion in this section of trends in degree attainment is restricted to broad disciplinary fields and comparisons among these fields. Changes in degree attainment patterns within a field may be important, but they are beyond the scope of this analysis. For example, a recent study of degrees awarded in psychology found that the fastest growth has occurred in the number of psychologists trained as health service providers, whereas training of academic or research-oriented psychologists has declined. (See American Psychological Association, 1985.) Another example is the increasing importance of the Ph.D., compared to the M.D., in biomedical research. (See National Science Board, 1986a, pp. 97-98.)

[8] Disciplinary practices regarding the master's degree vary. Master's degrees may be considered a terminal degree in some fields, while in Ph.D. programs the master's may or may not be part of the normal path to the Ph.D.

[9] National Research Council (1985), pp. 7-8.

[10] NSF (1987b).

[11] National Research Council, 1986b.

[12] NSF (1987b), p. 30.

[13] Ibid., p. 97.

agencies on their obligations for various activities in academic science and engineering.[14]

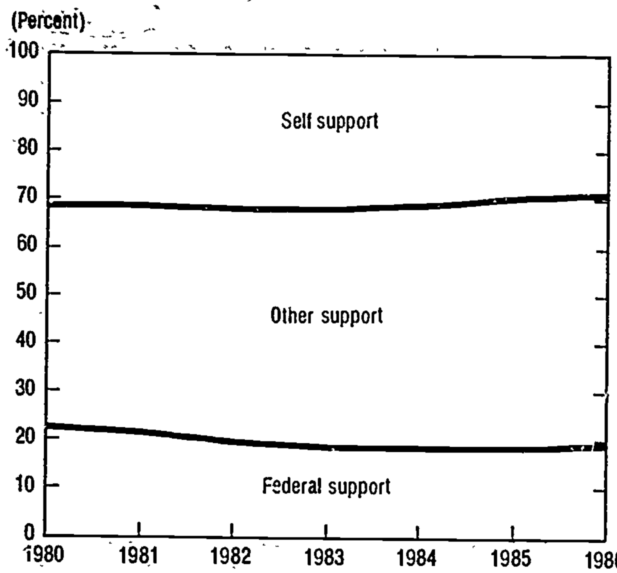
### Source of Support

Approximately 71 percent of the full-time S/E graduate students in U.S. doctorate-granting institutions received some form of financial aid in 1986; this percentage has not changed more than 1 or 2 points since 1980. (See appendix table 2-12.) When changes in the sources of graduate student financial aid are contrasted with enrollment changes over the same period, some noticeable shifts in source of support become evident. While full-time S/E enrollments increased at an annual average rate of 2.0 percent from 1980 to 1986, the number of students reporting the Federal Government as the main source of assistance decreased 0.5 percent over the same period, although the 1985-86 percentage change was positive. (See below.) In contrast, students reporting their main support from some source other than the Federal Government or self-support increased at an average annual rate of 3.8 percent from 1980 to 1986. (See figure 2-4.) The number of students who paid for most or all of their own graduate S/E education increased from 1980 to 1986 at an average annual rate of 1.1 percent;[15] this growth was slightly behind that in enrollments.

Over all science and engineering fields, the yearly proportion of full-time graduate students reporting their main support from Federal sources has declined, going from 23 percent in 1980 to 20 percent in 1986. However, the number reporting Federal support in 1986 was up by 4.9 percent from 1985 across all S/E fields combined. Support of graduate students in engineering and computer science led these increases at 10.5 percent and 15.9 percent, respectively.

Federal support increased as the main source of support in the environmental and agricultural sciences in 1986 over 1985, in contrast to overall negative trends in such support since 1980. Federal sources as the main support for full-time graduate S/E students in the social sciences continued its downward trend.

Figure 2-4.
**Major source of support of full-time S/E graduate students in doctorate-granting institutions**




See appendix table 2-12. Science & Engineering Indicators — 1987

### Financial Support by Type

The decline in fellowships and traineeships noted in *Science Indicators—1985* has been reversed in recent years. Such awards to graduate S/E students increased 1.2 percent from 1985 to 1986, although the 1980-86 trend remained negative. (See appendix table 2-13.) The most noteworthy increases from 1985 to 1986 were observed in computer science (10.7 percent), engineering (3.8 percent), and the social sciences (4.3 percent). Research assistantships have shown strong growth as a preferred mechanism of support in all fields, but especially in engineering (14.3 percent) and computer science (13.1 percent).

### Support by Gender and Source

While women have increased their share of earned doctorates over the past decade, their proportions in S/E fields—both as graduate students and as doctorate recipients—are still far below those of men.

In a world of equal qualifications, equal interests, and unbiased support patterns, financial support of males and females in S/E graduate education should mirror the proportions of male and female enrollment. In practice, however, this ideal is not achieved. (See appendix table 2-22.) Several differences become apparent when male and female graduate S/E support are compared by funding source and field of study. The Department of Defense (DoD) and foreign sources provide more financial aid to

[14] Both of these indicators have limitations. For example, the census of academic institutions offering S/E doctorates only reports on the source and type of major support for the graduate student. Since students often attend graduate study with a package of financial aid from different sources and of different types, many of these sources are not reported, leading to under-reporting of virtually all support sources. Additionally, the data contain no dollar value of the support received.

Another source of data on student financial aid is the reports made by students upon attaining their doctorates. This survey is a full census of the population of students receiving a doctorate in an S/E field each year. Again, however, the data are limited to the main source of support and ignore the amount of financial aid received.

The problem with the second type of indicator—Federal obligations for academic science and engineering support on the graduate level—is that it covers only a portion of the Federal support provided for graduate S/E study. While the indicator captures Federally funded fellowships, traineeships, and training grants, it misses the substantial monetary support of graduate S/E students with research assistantships.

[15] Federally guaranteed student loans may be included in this figure.

graduate S/E males, at least in part because of male domination in the fields of concern to the armed forces and in those chosen by foreigners studying in U.S. institutions. The Department of Health and Human Services (HHS), in contrast, most often funds females out of proportion to their share of enrollment in most fields. This pattern is also true of the National Institutes of Health, part of HHS. The National Science Foundation, in contrast, more heavily funded males than would be expected from their enrollment shares.

Across all sources of main support, computer science and mathematics stand out as fields in which women receive less funding than their proportions in the fields would suggest. Females also listed "self support" as the main source of their graduate education funds more often than their enrollment shares alone would predict. (See appendix table 2-22.)

## INSTITUTIONS OF S/E HIGHER EDUCATION

This section discusses two types of indicators. The first is concerned with the relationships among various groups of institutions: those which perform the most research and development (R&D), those which award S/E degrees at various levels, and those which award S/E baccalaureates to students who then go on to obtain S/E Ph.D.'s at some other institution. A second set of data shows characteristics of the faculties in the Nation's institutions of higher S/E education: their main activities on campus, their age distributions, and changes in their distribution across S/E fields in recent years.

### The Producers of S/E Doctorates

Two recent analyses[16] of the baccalaureate origins of S/E Ph.D.'s found that:

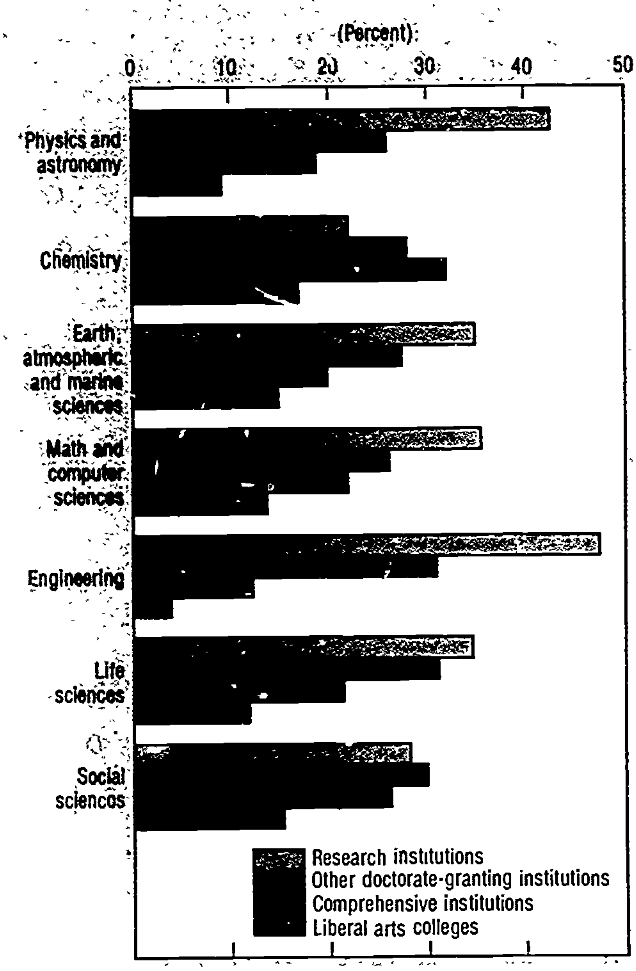
- Most S/E Ph.D.'s earned their baccalaureates at research-intensive and other doctorate-granting institutions;
- The proportion of S/E Ph.D.'s earning their baccalaureates at research-intensive institutions has declined over the past few decades;
- The baccalaureate origins of Ph.D.'s differ by gender and racial/ethnic group; and
- A small group of selective small universities and colleges produces relatively large percentages of their baccalaureates who go on to obtain S/E Ph.D.'s.

These results are expanded on in the following paragraphs.

*Large Producers of S/E Ph.D.'s*. Using a slight modification of the "Carnegie" scheme for classifying institutions,[17] the National Research Council found that of all S/E Ph.D.'s awarded in 1984 to persons who attended

[16]National Research Council (1986b), and Lois Peters, unpublished tabulations.

Figure 2-5.
**Distribution of 1984 S/E Ph.D.'s, by institutional type of baccalaureate-granting institution[1]**




[1]Omits specialized institutions and institutions not classified by type.
See appendix table 2-14. Science & Engineering Indicators — 1987

[17]The scheme used was as follows:

- Research-intensive universities. the 50 leading universities in terms of Federal financial support, plus 50 or more Ph.D.'s awarded in 1973-74.
- Other doctorate-granting universities (128 institutions). 20 or more Ph.D.'s awarded in 1973-74, or 10 or more in at least three fields.
- Comprehensive institutions (548 institutions): liberal arts programs plus at least one other professional or occupational program; highest degree awarded is the master's, or the Ph.D. program is extremely limited.
- Liberal arts schools (430 institutions): predominantly bachelor's level with a strong liberal arts tradition.
- Other (80 institutions). exclusively or almost exclusively technical or professional in such areas as medicine, theology, business, etc.

U.S. undergraduate institutions, 63 percent of their undergraduate degrees had been earned at research-intensive and other doctorate-granting institutions. (See figure 2-5.) The baccalaureates of 58 percent of 1984 physical sciences Ph D.'s, 78 percent of engineering, 65 percent of life sciences, and 58 percent of social sciences, had been awarded by these research-intensive institutions.

Engineering Ph.D.'s were the most likely to have earned their baccalaureates at Ph.D.-granting institutions. In contrast, chemistry Ph.D. earners were more likely than any other group of scientists to have obtained their baccalaureates at "comprehensive" or liberal arts colleges. These two types of institutions awarded 49 percent of the baccalaureates to U.S. citizens who obtained Ph.D.'s in chemistry in 1984.

Similar findings were made using a different institutional classification scheme and different time frame.[18] This analysis divided the baccalaureate-granting schools as follows: schools granting more than 40 S/E Ph.D.'s in 1981-82, 40 or fewer, up to the master's degree, up to the bachelor's degree, and foreign institutions. (See appendix table 2-15.) This analysis found decreasing percentages of baccalaureates awarded to S/E Ph.D. earners by the large Ph.D.-granting institutions between 1963 and 1983. Considerable increases in the importance of non-U.S. institutions in producing undergraduates who eventually obtain their Ph.D.'s in the U.S. were found in engineering and the physical sciences.

Women S/E Ph.D. earners from 1983 to 1985 were slightly less likely to have obtained their baccalaureates at research-intensive or other doctorate-granting institutions than men (55 percent versus 59 percent). (See appendix table 2-16.) Black S/E Ph.D. earners were considerably less likely to have attended these institutions than whites (40 percent versus 61 percent).

*"Productive" Producers of S/E Ph.D.'s.* The data discussed above considered only the total output of the undergraduate institutions in terms of the number of baccalaureate earners who eventually obtained Ph.D.'s. With this approach, the baccalaureate "source" institutions are dominated by the larger universities. Another approach is to compare the percentage of a school's baccalaureate earners who go on to obtain Ph.D.'s.

The National Research Council compared the output and productivity of specific undergraduate institutions for the 1984 Ph.D. cohort. Across all fields, the study found that of the 30 leading undergraduate institutions granting at least 50 baccalaureates[19] in 1974, only 1 of these 30 was a primarily undergraduate school (City University of New York-Brooklyn), based on total output of baccalaureates going on to obtain the Ph.D. in all fields. (See appendix table 2-17.) In contrast, of the 30 most "productive"[20] undergraduate institutions in 1974, 19 of these schools were neither research-intensive nor other doctorate-granting schools.

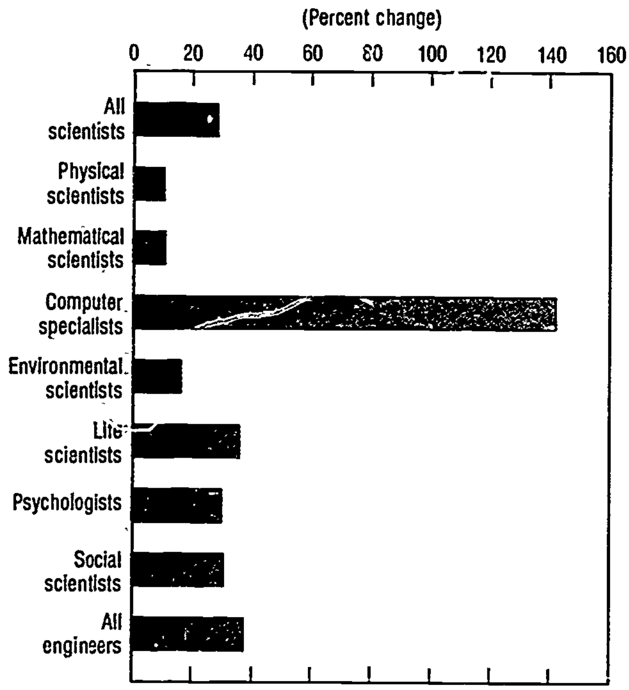
The same analysis identified "productive" undergraduate institutions which award undergraduate degrees to eventual S/E Ph.D. recipients out of proportion to their size and importance in the research and development community. For example, 6 of the 10 most "productive" producers of baccalaureates for 1984 Ph.D.'s in the physical sciences were primarily bachelor's institutions or specialized schools. Corresponding counts were 4 out of 10 for engineering, 4 of 10 for the life sciences, and 8 of 10 for the social sciences. (See appendix table 2-18.)

## S/E Higher Education Faculties

U.S. institutions of higher education[21] employed 202,000 doctoral scientists and engineers in 1985. Of these, 180,000 were doctoral *scientists*, about 54 percent of the total doctoral scientists employed in the U.S. The approximately 22,000 doctoral engineers employed by 4-year institutions represented some 33 percent of the total U.S. engineering workforce with Ph.D.'s in 1985.

Virtually all of the major S/E fields have experienced growth in the academic employment of Ph.D.'s (see figure 2-6), although at different rates of growth. Four-year

Figure 2-6.
**Growth in academic employment of doctoral scientists and engineers between 1977 and 1985**




See appendix table 2-19. Science & Engineering Indicators — 1987

[18]Lois Peters, unpublished tabulations.

[19]The National Research Council analysis used a cut-off of at least 50 baccalaureates in order to avoid domination by the very small, specialized institutions. See National Research Council (1986b).

[20]In terms of the number of baccalaureates from a particular school who go on to obtain Ph.D.'s. A "productivity" measure is derived by dividing the Ph.D. earners with a baccalaureate from a specific school by the number of baccalaureates produced by that school.

[21]Defined here as 4-year colleges and universities only.

institutions increased the employment of doctoral computer scientists by 142 percent from 1977 to 1985, a far higher total growth rate than for any other major field. Other fields with considerable increases since 1977 included the life sciences (35.4 percent), engineering (36.9 percent), the social sciences (30.3 percent), and psychology (29.7 percent). (See appendix table 2-19.)

The increase in the employment of doctoral scientists and engineers by 4-year institutions has been accompanied by an increase in the research and development activities of these academic employees. Between 1981 and 1985, the percentage of doctoral scientists and engineers on 4-year campuses who reported teaching as their primary activity increased at a *slower* rate than total employment growth in all major fields except computer science. In contrast, the proportions of doctoral scientists and engineers at 4-year schools reporting R&D activities as their primary work emphasis increased at rates *greater* than employment growth in all fields except computer science, the life sciences, and psychology from 1981 to 1985. (See appendix table 2-20.)

Computer science led most trends from 1981 to 1985, no doubt because of the rapid transformation and stabilization of this field on the Nation's campuses. In those 4 years, computer science experienced:

- A 79.0-percent growth in the number of Ph.D. holders reporting teaching as their primary activity;
- A 73.5-percent growth in the number of Ph.D. computer scientists employed at 4-year institutions; and
- A 64.4-percent growth in the number of Ph.D. computer scientists reporting R&D as their primary activity on campus, compared with the next highest such increases of 23.9 percent by engineering Ph.D.'s and 22.5 percent by mathematics Ph.D.'s.

The S/E doctoral faculties of the Nation's 4-year institutions also held, in general, higher rank in 1985 than in 1981. (See appendix table 2-21.) In 1985, proportionately more doctoral faculty members held the rank of full professor than in 1981 in all large fields except computer science and engineering. Fields experiencing increases in the proportions holding the rank of full professor display in general decreasing proportions holding either associate or assistant professor status. Only computer science, mathematics, and engineering showed increases in the proportions holding assistant professorships in 1985 over 1981, because of the more recent growth and increased new hiring in these fields.

The age distributions of doctoral faculties reflect the increases in academic rank discussed above. (See appendix table 2-19.) In all fields combined, the proportions younger than 40 years have decreased since 1977. When observed field by field, mathematical scientists and engineers—as might be expected from the recent growth of these fields—have shown slight increases in the proportions of doctoral faculty 30 years or younger. The computer/information sciences, which might for the same reason also have been expected to show an increasing proportion of relatively younger faculty, have in fact experienced a decrease in the *proportions* of faculty under 40 years and significantly increased the proportion between 40 and 49 and more than 60. This unexpected trend in age distribution may be because of the reputed large amount of field switching into computer science from other fields.

## REFERENCES


American Council on Education, *Towards a National Policy for Undergraduate Science Education* (Washington, DC: American Council on Education, n.d.).

American Psychological Association, Committee on Employment and Human Resources, *The Changing Face of American Psychology* (Washington, DC: American Psychological Association, 1985).

Carnegie Foundation for the Advancement of Teaching, *Sustaining the Vision* (Princeton: Carnegie Foundation for the Advancement of Teaching, 1985).

Council of Graduate Schools, *Recent Developments in Graduate Programs*, proceedings of October 13, 1982, conference (Washington, DC. Council of Graduate Schools, n.d.).

Engineering Manpower Commission, *Engineering and Technology Enrollments, Fall 1985, Parts I and II* (Washington, DC: American Association of Engineering Societies, 1986).

Government-University-Industry Research Roundtable and the Franklin Institute, "Nurturing Science and Engineering Talent: A Symposium," briefing papers for a symposium held at the Franklin Institute, Philadelphia, September 29, 1986.

Government-University-Industry Research Roundtable and the Franklin Institute, "Nurturing Science and Engineering Talent: a Symposium," briefing papers for a symposium held at the Franklin Institute, Philadelphia, September 29, 1986.

Hauptman, A.M., *Students in Graduate and Professional Education: What We Know and Need to Know* (Washington, DC: The Association of American Universities, 1986).

Lee, V., *Access to Higher Education. The Experience of Blacks, Hispanics, and Low Socio-Economic Status Whites* (Washington, DC: American Council on Education, 1985).

National Research Council, *The Access and Success of Blacks and Hispanics in U.S. Graduate and Professional Education* (Washington, DC: National Academy Press, 1986a).

National Research Council, *Doctorate Recipients from U.S. Universities, 1984* (Washington, DC: National Academy Press, 1986b).

National Research Council, Panel on Engineering Graduate Education and Research, *Engineering Graduate Education and Research* (Washington, DC: National Academy Press, 1985).

National Research Council, Panel on Undergraduate Engineering Education, *Engineering Undergraduate Education* (Washington, DC: National Academy Press, 1986c).

National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1986a).

National Science Board, *Undergraduate Science, Mathematics and Engineering Education* (Washington, DC: Government Printing Office, 1986b).

National Science Foundation, Division of Policy Research and Analysis, "The Science and Engineering Pipeline," mimeo, PRA Report 87-2 (Washington, DC: NSF, 1987a).

National Science Foundation, Division of Science Resources Studies, *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook* NSF 86-305, revised (Washington, DC: NSF, 1987b).

Office of Science and Technology Policy, Panel on the Health of U.S. Colleges and Universities, *Report of the White House Science Council* (Washington, DC: Government Printing Office, 1986).

Smith, B.L.R., ed., *The State of Graduate Education* (Washington, DC: The Brookings Institution, 1985).

U.S. Department of Education, Office of Educational Research and Improvement, *The Condition of Education 1986* (Washington, DC: Government Printing Office, 1987).

U.S. Congress, House Committee on Education and Labor, "Education and Training for American Competitiveness Act: Report," Report No 99-597 (Washington, DC: U.S. House of Representatives, 1986).

# Chapter 3
# Science and Engineering Workforce

# Science and Engineering Workforce

## HIGHLIGHTS

- *Employment in science and engineering (S/E) jobs reached 3.9 million in 1986, an average annual increase of 6.3 percent per year since 1976.* During this period, employment of scientists grew at a faster rate than that of engineers (7.1 percent per year versus 5.8 percent). Growth in scientific employment was greatly influenced by computer specialists, however, who accounted for about two-fifths of the total increase in scientific jobs. (See pp. 53-54.)
- *Private indust· · provided employment for 66 perce.nt (2.6 million) of the N n's scientists and engineers in 1986, up from 62 percent (1.3 million) in 1976.* Educational institutions ranked a distant second with 15 percent (0.6 million) of all S/E employment. Almost 70 percent of those employed in industrial S/E were engineers, while scientists represented more than 84 percent of S/E employment in academia. (See pp. 55, 58.)
- *Although the percentage of women scientists and engineers in the workforce has steadily increased since 1976, women employed in S/E remained underrepresented in 1986, accounting for only 13 percent of the science and engineering workforce.* By comparison, women represent almost one-half of the total U.S. workforce. (See pp. 61-63.)
- *Blacks remained underrepresented in the S/E workforce in 1986, accounting for only 2.5 percent of all scientists and engineers.* In contrast, blacks make up 10 percent of total U.S employment and 6 percent of the professional and related workforce. (See pp. 63-64.)
- *Labor market indicators suggest that in 1986 there was generally sufficient demand to accommodate the science and engineering workforce.* This was characterized by the high labor force participation rate (94.5 percent) and low unemployment rate (1.5 percent) for scientists and engineers. (See p. 64.)
- *High-technology industrial growth and the increasing use of high-technology goods and services in the economy as a whole will lead to increasing demand for scientists and engineers in industry.* Demand for S/E personnel is expected to increase by 36 percent between 1986 and 2000, with the highest anticipated growth expected for computer specialists (76 percent) and the lowest for chemists (11 percent). (See pp. 67-68.)
- *The supply of new science and engineering graduates may decline over the next decade because of an expected decrease in the college-age population.* Increased participation by women and minorities in undergraduate S/E programs and/or expanded enrollment of older students and foreigners may be required to eliminate potential shortages of new S/E graduates. (See pp. 64, 68-70.)
- *The United States has a higher proportion of scientists and engineers in the labor force than has Japan (2.8 percent as compared to 2.5 percent).* In addition, the U.S. participation of women in S/E is 2.5 times greater than that of Japan. The United States is also graduating more engineers at both the bachelor's and doctorate degree levels. (See pp. 70-72.)

The more than 4.6 million scientists and engineers[1] employed in the United States in 1986 contribute in countless ways to the welfare and technological progress of the Nation. They are essential to the functioning of our advanced industrial society and have an impact on society disproportionate to their numbers.

The past decade has witnessed a substantial growth in demand for workers in science and engineering activities. New and expanded programs in research and development (R&D), defense, health, and higher education all contributed to this growth. There has also been a shift in this decade in the industrial demand composition for S/E personnel as nonmanufacturing industries begin to overtake manufacturing ones as the major employment sector.[2] These changes have been generally accomplished through a flexible labor force and educational system capable of providing the personnel and training required, an increasing utilization of foreign-origin personnel has also been a significant factor.[3]

While there were substantial shortages for many S/E occupations in the early 1980's,[4] there was, by 1986, a sufficient supply of scientists and engineers to meet most

[1]See appendix table 3-1. In general, a person is considered a scientist or engineer if (1) the highest degree held is in a science or engineering field, and (2) the person is either employed in a science or engineering job or professionally identifies himself or herself as a scientist or engineer based on total education and work experience.

[2]See NSF (1987a), back cover.

[3]NSF (1986a), p. 37

[4]NSF (1986b), back cover.

of the industrial sector's needs. Within the academic sector, however, low rates of faculty retirement and declining rates of growth in institution size have produced a progressively older science and engineering academic community.[5] Another persistent problem is a continuing shortage of Ph.D.'s for employment in engineering schools.[6] Since these patterns are not likely to change in the near future, there is some concern as to the ability of colleges and universities to maintain the high caliber of S/E research and education.

This chapter reviews trends in utilization patterns of scientific and technical personnel, examines the dynamics of the supply of scientists and engineers, discusses recent labor market conditions, and presents forecasts of requirements through the 1990's.

## UTILIZATION OF SCIENTIFIC AND TECHNICAL PERSONNEL

### Trends in S/E Employment

Trends in the utilization of scientific and technical personnel, when reviewed against the backdrop of other economic developments, provide indicators of national priorities in assigning human resources to science and technology. In the last decade, employment of those in science and engineering jobs has grown more rapidly than have total U.S. employment and overall economic activity: this indicates substantial shifts in national activity patterns toward those related to science and technology. Moreover, this growth has been shared by all S/E occupations, particularly computer specialties. The proportion of scientists and engineers employed by the industrial and educational sectors has continued to increase, while the percentage working in the Federal Government and other sectors has declined.

It is useful to distinguish between the employment of those who are considered scientists and engineers because of their education and experience and the employment of those who have jobs in S/E. For a variety of reasons (mostly "voluntary" ones, such as better pay, promotions, and location preference), some scientists and engineers hold jobs outside their own or related fields. Of the approximately 4.6 million employed scientists and engineers in 1986, 15 percent (700,000) reported that they held jobs outside of science and engineering; scientists (23 percent) are more likely than engineers (8 percent) to hold such positions. (See figure O-10 in Overview.) Being employed in non-S/E jobs does not necessarily mean that these scientists and engineers are underutilized (see p. 65), since their training and education may provide valuable insights on their nontechnical activities. Trends in the numbers of persons employed in science and engineering work relative to all U.S. workers or other economic variables are direct indicators of national priorities for technical compared to nontechnical activities.

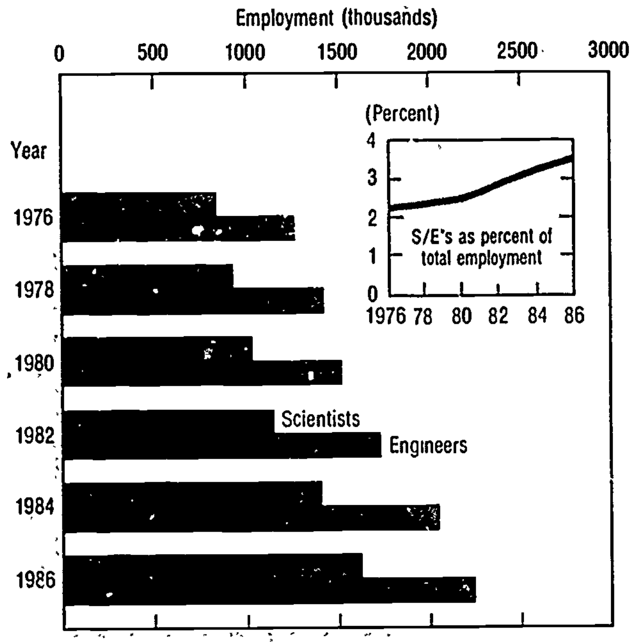
The recent emphasis on increasing defense expenditures, levels of research and development expenditures, and growth in demand for high-technology goods and services all would suggest that S/E employment would be expected to claim a higher proportion of overall U.S. employment. The 1986 data confirm this premise, as the U.S. workplace continues its trend of putting greater emphasis on scientific and engineering activities. Between 1976 and 1986, the number of those employed in S/E jobs expanded at a substantially faster rate than did either total employment or overall economic activity as measured by gross national product (GNP). (See table O-1 and figure O-9 in Overview.)

During the last decade, the S/E workforce[7] nearly doubled, increasing four times as rapidly as total U.S. employment. Science and engineering employment grew by 6.3 percent per year between 1976 and 1986, reaching almost 4 million. (See figure O-11 in Overview.) In the same period, total U.S. employment increased by 2.1 percent per year;[8] the share of the total workforce devoted to science and engineering increased from 2.4 percent to 3.6 percent. (See figure 3-1.) Finally, real GNP increased at an annual rate of only 2.7 percent between 1976 and 1986.

As indicated above, much of the increase in S/E employment can be attributed to the relatively greater uti-

[7]Includes only those scientists and engineers employed in science or engineering jobs, unless otherwise indicated.
[8]Civilian employment, 16 years of age and over.

Figure 3-1.
**Scientists and engineers employed in S/E jobs**




See appendix tables 3-1 and 3-2.

Science & Engineering Indicators — 1987

[5]Paula Stephan, as reported in Cunningham (1986), p. 6
[6]Doigan (1984), pp. 50-55.

lization of scientists and technical personnel in the economy—presumably because of greater scientific and technical sophistication of products and production processes, Government expenditures for defense and other programs requiring significant inputs of S/E talent, and other factors.

Growth in the employment of scientists and engineers between 1976 and 1986 varied substantially across fields. Employment in science occupations increased at an average annual rate of 7.1 percent, reaching more than 1.6 million in 1986. Computer specialists accounted for almost two-fifths of the total employment increases among scientists; if computer specialists are excluded, employment growth for scientists averaged 5.5 percent per year. In 1986, 2.2 million persons held engineering jobs, representing an average annual rate of increase of 5.8 percent. The largest relative growth in engineering was recorded by electrical and astronautical/aeronautical engineers. (See figure O-11 in Overview.) Engineering employment growth would probably have been higher if not for the engineer supply constraints experienced in the late 1970's and early 1980's.[9]

The trends observed during the 1976-86 period have become more pronounced since the early eighties. Between 1980 and 1986, employment of scientists rose at an annual rate of 8.4 percent per year. This growth was still influenced substantially by computer specialists, whose employment increased at an annual rate of 14.2 percent. This growth in the number of computer specialists, compared to the much smaller number of people earning degrees in the field, suggests substantial field mobility. Excluding computer specialists, employment of scientists increased by 6.8 percent per year. Employment of engineers also grew at an annual rate of 6.8 percent during the 1980-86 period. (See appendix table 3-1.)

Employment of S/E doctorate holders reached 400,000[10] in 1985—an increase of 82 percent (5.1 percent per year) since 1973. Since 1981, employment growth of doctoral scientists and engineers has slowed, however, increasing by less than 4 percent per year versus 5.7 percent per year between 1973 and 1981.

While educational institutions have remained the primary source of S/E doctoral employment, the share of Ph.D. scientists and engineers employed by industry has been steadily increasing. Industry employed 31 percent (126,000) of doctoral scientists and engineers in 1985; this was up from 24 percent in 1973. The 212,000 Ph.D. scientists and engineers in educational institutions in 1985 represented about 53 percent of the employed total, down from 59 percent in 1973.

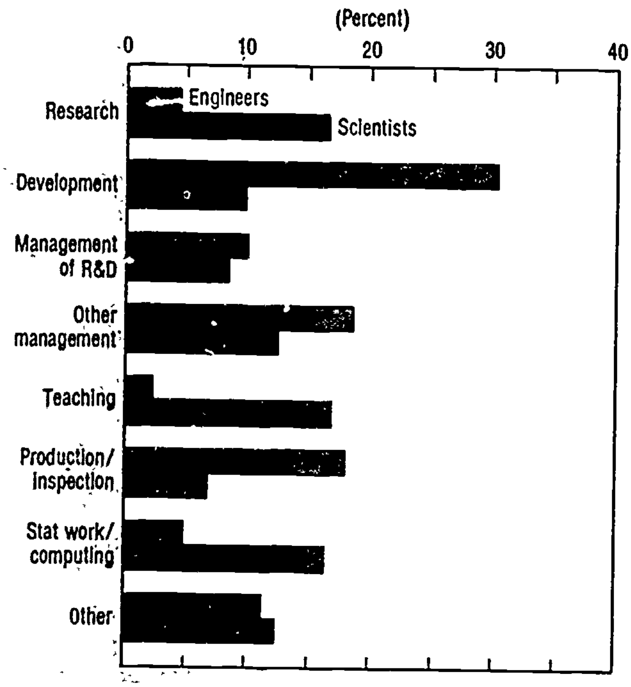
Scientists at the doctoral level continued to outnumber engineers by about five to one in 1985, with growth rates since 1973 varying considerably by field. The physical and mathematical sciences experienced below average annual growth rates, while computer specialties was the fastest growing field of employment. Between 1973 and 1985, Ph.D. employment in this field grew at an annual rate of more than 15 percent per year, from 2,700 in 1973 to 15,000 in 1985. Almost 60 percent of the increased employment of doctoral computer specialists took place in industry; about 31 percent occurred in educational institutions.

## Trends in Science and Technology Activities

Trends in the primary work activities of scientists and engineers are direct indicators of the character of U.S. science and technology. These activities are measured by the number and proportion of those engaged in performing R&D, teaching, and other activities (see figure 3-2), and vary considerably by sector of the economy. Between 1976 and 1986, there was a substantial increase in the relative proportions of scientists and engineers primarily engaged in production, reporting and related activities, and teaching. The proportions of those working in development rose slightly, while the relative proportions of those primarily engaged in general management, R&D management, and research declined.

The number of scientists and engineers primarily engaged in research and development almost doubled in the 1976-86 period. By 1986, R&D was the primary activity of 31 percent of the Nation's scientists and engineers, with an additional 10 percent (about 370,000) working in R&D management. Scientists were more like-

Figure 3-2.
**Primary work activities of employed scientists and engineers: 1986**




See appendix table 3-4. Science & Engineering Indicators — 1987

[9]NSF (1982).

[10]Includes 35,900 doctoral scientists and engineers employed in non-S/E activities. All S/E doctorate holders are considered by NSF to be employed as scientists and engineers, even though they may not be employed in S/E activities.

ly than engineers to report research as their primary activity (17 percent versus 4 percent), while engineers were more likely to be involved in development and R&D management (41 percent versus 19 percent). Those holding S/E doctorates were employed in similar proportions. In 1985, 33 percent of doctoral scientists and engineers were working primarily in research and development, while an additional 9 percent cited R&D management as their primary activity.

Employment in teaching activities grew at a somewhat higher rate than did overall S/E employment during the 1976-86 period (8.3 percent versus 6.3 percent per year). About 9 percent of all scientists and engineers reported teaching as their primary work activity in 1986, with scientists more likely than engineers to report teaching as their principal activity (17 percent versus 2 percent). This contrast is partially a result of differences in educational levels: scientists are more likely to hold academic teaching positions than are engineers because a larger proportion of scientists holds doctorates (18 percent versus 3 percent). At the doctoral level, however, 28 percent of scientists and engineers reported teaching as their primary work activity in 1985; this was down from 36 percent in 1973. The decline in the proportion of doctorates reporting teaching as their primary activity is the result of a shift in the concentration of Ph.D.'s from academia to industry (see discussion below on sectoral trends), with the attendant change in work activities.

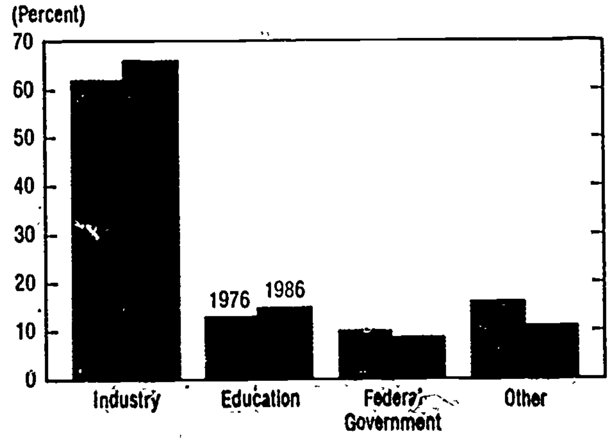
From 1976 to 1986, production and related activities—including quality control—were among the fastest growing S/E work areas, especially for engineers. The number of scientists and engineers primarily engaged in these activities rose by an average of almost 9 percent per year to about 512,800 in 1986—398,500 engineers and 114,300 scientists.

## SECTORAL TRENDS IN THE S/E LABOR FORCE

Private industry was the major employer of both engineers and scientists (66 percent or 2.6 million) in 1986, with engineers more likely than scientists to work in this sector (80 percent versus 48 percent). Industry also employed more than 1.6 million S/E technicians as support personnel. Since 1976, the share of scientists and engineers employed in business and industry has increased by about 5.0 percent, while declining slightly (1.5 percent) for the Federal Government. In 1986, the education sector ranked a distant second as an employer of scientists and engineers (15 percent or almost 573,000), employing 29 percent of all scientists, but only 4 percent of all engineers. (See figures 3-3 and 3-4.)

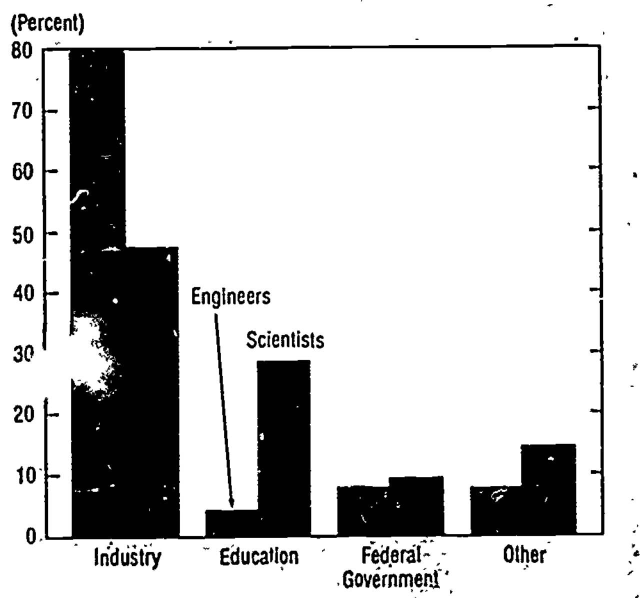
Sectoral changes have been more pronounced at the doctoral level. Although educational institutions remained the primary employer of doctoral scientists and engineers in 1985, the proportion employed in this sector has declined steadily since the early 1970's, while the industry share has increased. In 1973, 59 percent of all those holding S/E doctorates were in educational institutions and 24 percent were in business and industry, in 1985, these proportions were 53 percent and 31 percent, respectively. (See figure 3-5.)

Figure 3-3.
**Distribution of employed scientists and engineers, by sector of employment: 1976, 1986**




See appendix table 3-5. Science & Engineering Indicators — 1987

Figure 3-4.
**Distribution of employed scientists and engineers, by sector of employment: 1986**

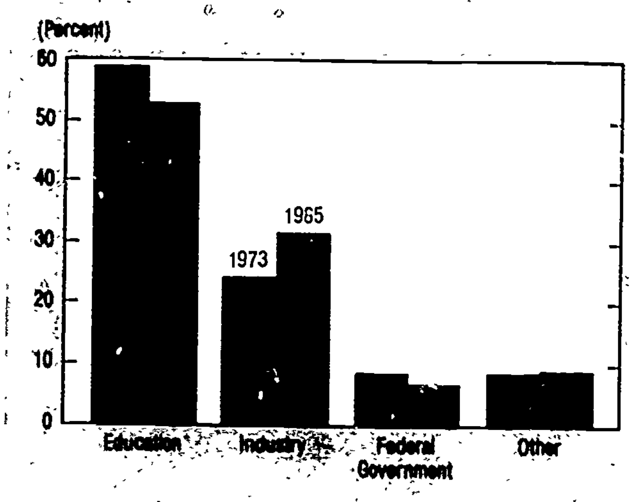



See appendix table 3-5. Science & Engineering Indicators — 1987

### Industry

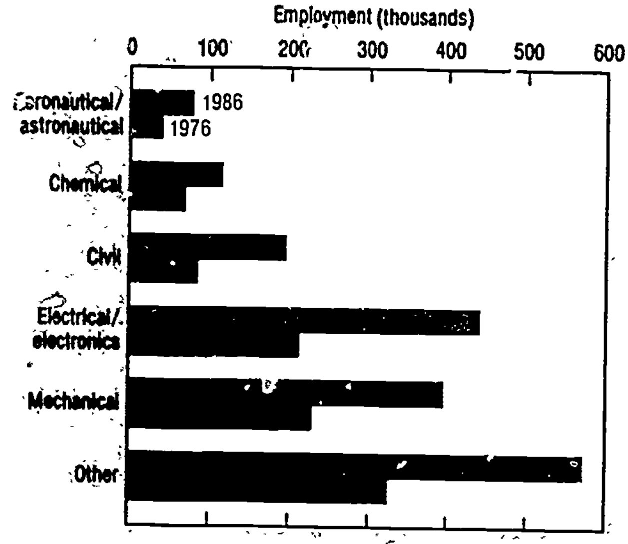
Between 1976 and 1986, business and industry experienced some dramatic changes in both the occupational and industrial distributions of its science, engineering, and technical workforce. Total S/E employment in private

Figure 3-5.
**Distribution of employed doctoral scientists and engineers, by sector of employment: 1973, 1985**




See appendix table 3-6. Science & Engineering Indicators — 1987

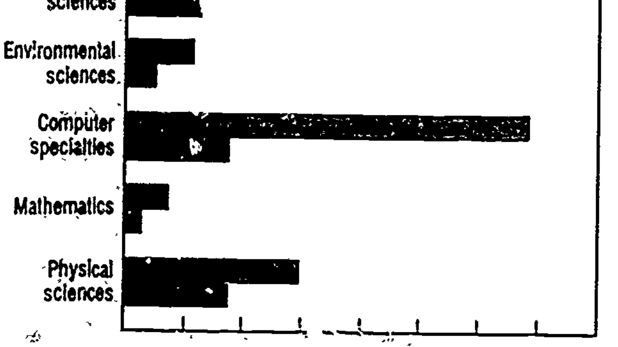
Figure 3-7.
**Engineers employed in industry, by field: 1976, 1986**




See appendix table 3-5. Science & Engineering Indicators — 1987

industry increased by an average of 7 percent per year, from 1.3 million in 1976 to almost 2.6 million in 1986. (See figures 3-6 and 3-7.) There was a gradual shift in S/E employment concentration from the manufacturing to the nonmanufacturing sector,[11] with the proportion of scientists and engineers employed in manufacturing industries declining from more than 57 percent in 1977[12] to about 55 percent in 1986. Of the scientists and engineers employed in industry in 1986, about 45 percent worked in the nonmanufacturing sector. (See figures 3-8 and 3-9.)

Figure 3-6.
**Scientists employed in industry, by field: 1976, 1986**



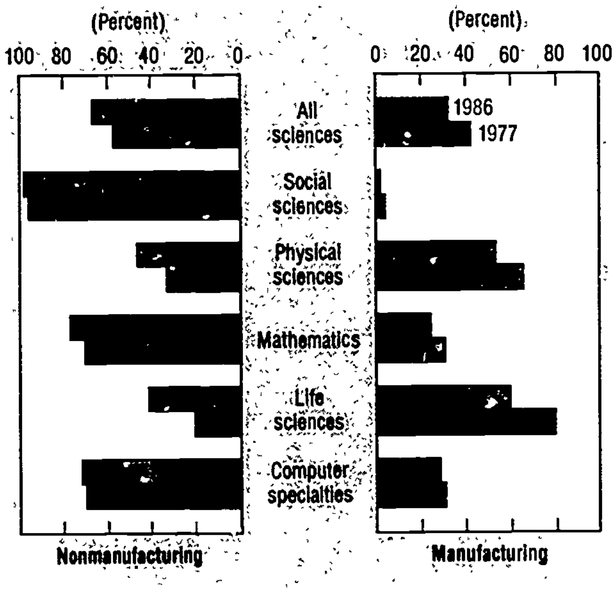

See appendix table 3-5. Science & Engineering Indicators — 1987

Much of the increase in S/E employment in the nonmanufacturing sector can be attributed to the rapidly expanding workforce of the service-producing industries, changes in S/E employment within the manufacturing sector, on the other hand, are almost entirely explained by structural change. Even though manufacturing industries experienced little or no growth in total employment levels between 1977 and 1986, science and engineering employment in this sector increased by an average of 4.9 percent per year. This growth—primarily because of the increased dominance of engineers, computer specialists, and mathematical scientists[13] within these industries—reflected a shift away from the labor-intensive production atmosphere of the seventies to the more "high-tech" and knowledge-intensive environment of the eighties.

Employment of S/E technicians became increasingly more prominent between 1977 and 1986, increasing from 0.9 million in 1977 to more than 1.5 million in 1986 (5.8 percent growth per year). Almost 80 percent of the increase occurred in the nonmanufacturing sector, again primarily because of the high concentration of service-producing industries in that sector. Computer program-

[11]See NSF (1987a), back cover.
[12]Earliest year in which data were available.
[13]Zampelli (1986).

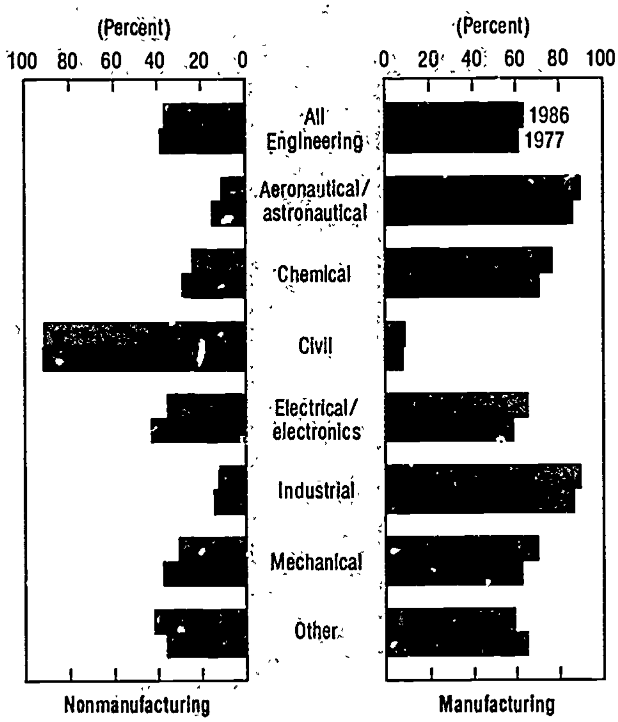
Figure 3-8.
**Percentage of scientists employed in industry, by sector and field: 1977, 1986**




See appendix table 3-7.

Science & Engineering Indicators — 1987

Figure 3-9.
**Percentage of engineers employed in industry, by sector and field: 1977, 1986**




See appendix table 3-7.

Science & Engineering Indicators — 1987

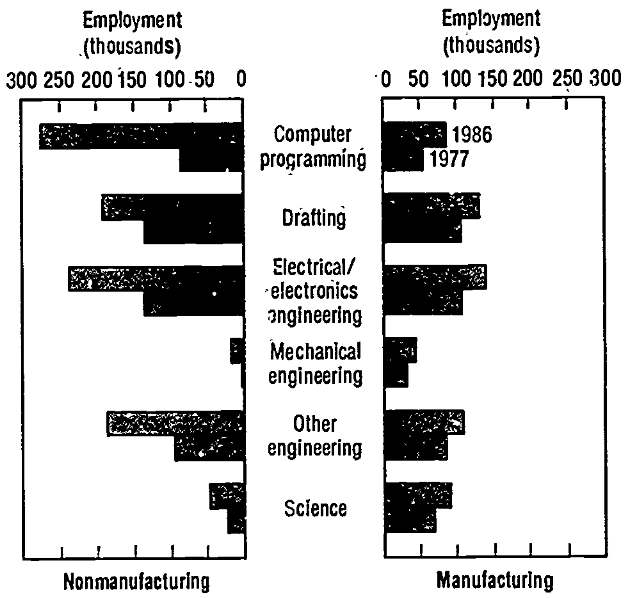
mer, electrical/electronics technician, and mechanical technician employment all showed substantial gains. (See figure 3-10.)

The shifts in industrial demand for scientists, engineers, and technicians over the last decade are the result of sweeping changes in industry makeup. Between 1976 and 1986, total private nonagricultural employment in the United States grew by almost one-third from 64 million to 83 million. This entire growth was in nonmanufacturing, more notably in non-blue-collar, jobs. However, even though total manufacturing *employment* did not increase during this period, manufacturing *production* (as measured by the industrial production index) rose by almost 40 percent.[14]

This separation of manufacturing production from manufacturing employment illustrates the transition from mid-1970's labor-intensive industries to 1980's knowledge-intensive industries. For example, it has been estimated that the manufacturing costs of the semiconductor microchip are about 70 percent knowledge—that is, research, development, and testing—and no more than 12 percent labor.[15] Similarly, for prescription drugs, labor represents only 15 percent of the cost, with knowledge representing almost 50 percent.[16] By contrast, in the most fully automated automobile plant, labor would still account for 20 to 25 percent of the costs.[17]

[14]Council of Economic Advisers (1987), p. 296.
[15]Drucker (1986), p. 778.
[16]Ibid.
[17]Ibid.

Figure 3-10.
**Science and engineering technicians employed in private industry, by sector and field: 1977, 1986**




See appendix table 3-8.

Science & Engineering Indicators — 1987

For the last 15 to 20 years, almost the entire shrinkage in manufacturing jobs in the U.S. has occurred in the large companies, beginning with the steel and automobile industry giants. Medium- and small-sized manufacturers have held their own or even added employees. Other developed countries, including Japan, have also been experiencing this reversal of the dynamics of size.

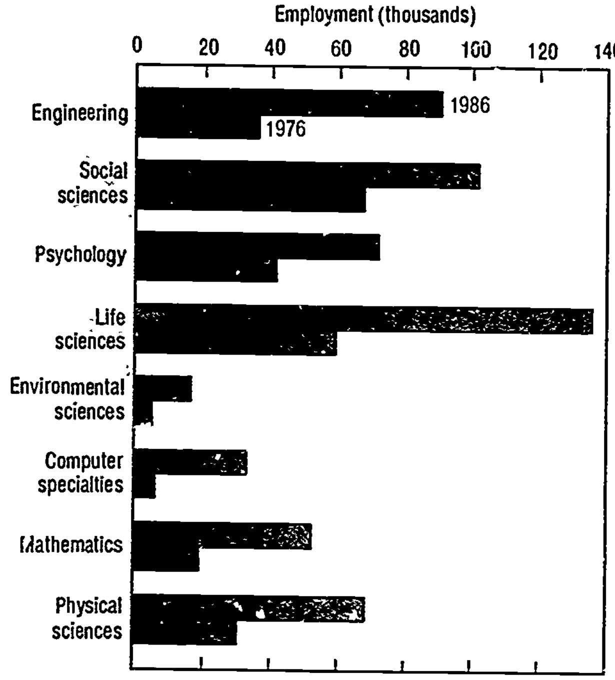
While the transition to a high-tech workforce over the last decade has been accompanied by increasingly greater demands for workers with S/E skills, the supply of such workers has not always been sufficient to meet industry needs. As noted previously, in the late 1970's and early 1980's many firms reported employee shortages in most engineering fields and computer specialties; however, by 1986, there appeared—in general—to be a nearly adequate supply of scientists and engineers. This balance has been brought about in part by field switching and a high reliance on foreign S/E personnel.[18]

## Educational Institutions

Overall demand for scientists and engineers in educational institutions[19] kept pace with the rate of the economy's growth in demand, increasing from 13 percent in 1976 to almost 15 percent in 1986. The ratio of scientists to engineers also remained constant at about 6 to 1. Of the approximately 573,000 scientists and engineers working in educational institutions in 1986, almost 84 percent were employed in scientific fields; one-half of these were either life scientists or social scientists. Of the 91,000 engineers in this sector, 17,000 were mechanical engineers and 25,000 were electrical/electronics engineers. (See figure 3-11.)

In general, academia experienced the same increasing demand for technical staff as did industry—especially for employees with engineering or computer science degrees. Moreover, because some universities and colleges in the early 1980's were unable to compete with the salaries offered by private industry, they lost faculty members in certain high demand engineering positions.[20] Lacking graduate candidates to fill these positions, educational institutions have increasingly relied on foreign academics (as in industry) to maintain their staffing levels.[21]

Figure 3-11.
**Scientists and engineers employed in educational institutions, by field: 1976 and 1986**




See appendix table 3-5.

Science & Engineering Indicators — 1987

## Federal Government

While the Federal Government was the largest single employer of scientists and engineers in the United States from 1976 to 1986, the proportion of scientists and engineers it employed declined in those years from 10.0 percent to 8.5 percent. In 1986, more than 54 percent of the 334,200 Federal scientists and engineers were employed in engineering occupations, of which almost one-half were either electrical/electronics or civil engineering. Of the 153,500 scientists in the Federal Government, 40,200 were life scientists and 32,100 were computer specialists.

Federal employment was more technologically intensive than the overall workforce: about 14 percent of all Federal white-collar employees worked in S/E occupations, compared to only 6 percent of total U.S. white-collar employment.[22] The Department of Defense (DoD) employed almost one-half of all Federal scientists and engineers, with the Department of Agriculture ranking a distant second (12.0 percent).[23]

## Other Sectors

Of the 423,700 scientists and engineers not employed in the above sectors in 1986, almost one-half (214,600) worked for State and local governments while 34 percent (143,900) were employed by nonprofit institutions. The remaining 16 percent were either in the military or other organizations.

[18]NSF (1986b), back cover.

[19]See chapter 5, "Academic R&D and Basic Research: Patterns of Performance."

[20]Hansen (1985), p. 6.

[21]NSF (1986a), p. 36.

[22]NSF (1987b).

[23]Ibid.

## DEMOGRAPHIC TRENDS: EDUCATIONAL ATTAINMENT

### Bachelor's and Master's Degrees

Partly in response to a perceived growth in employment opportunities, the number of college degrees awarded in engineering and computer science increased between 1976 and 1986. S/E graduates during this period benefited from higher employment rates. The proportion of bachelor's degree recipients employed in S/E occupations rose from 45 percent to 64 percent; S/E employment of master's degree recipients increased from 77 percent to 84 percent. (See figure 3-12.)

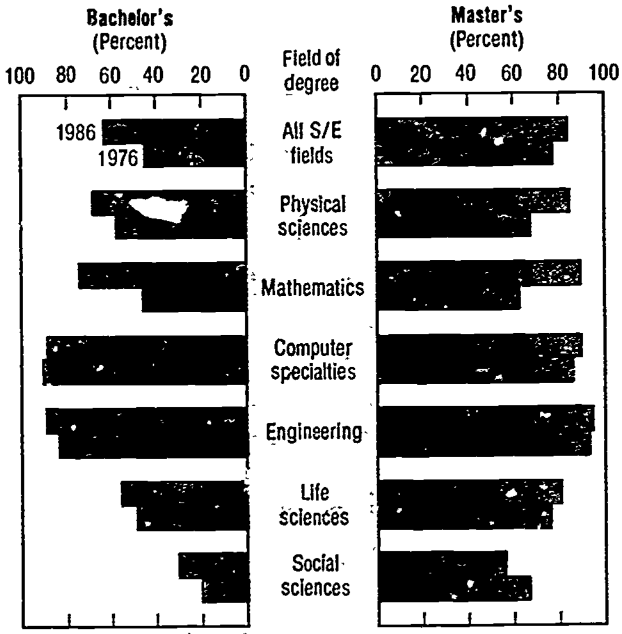
The strong demand for graduates in computer science, engineering, and mathematics was consistent with the high levels of employment in S/E occupations. Although there was substantial variation among fields, acquisition of a master's degree generally provided more S/E employment opportunities. While at least 90 percent of master's degree recipients in most major fields were employed in S/E occupations, the rates for life and social sciences were considerably lower—81 percent and 56 percent, respectively.[24]

In general, the S/E employment rates for men were higher than those for women at both the bachelor's and master's degree levels. The concentrations of each sex in particular fields contributed to some of the difference in rates. For instance, the low S/E employment rate in the social sciences coupled with the concentration of women in these fields effectively lowered the average employment rate. Moreover, the high S/E employment rate in engineering—in which men were predominant—had the effect of raising men's average S/E employment rate.

The continuing high demand for computer specialists exceeded the supply of computer science majors and attracted graduates from other S/E fields, especially mathematics and engineering. In 1986, about four-fifths of both the bachelor's and master's degree recipients working as computer specialists were computer science graduates; this was an increase over 1984 levels, when about two-thirds of the bachelor's and master's degree recipients had computer science degrees. The rising share reflects the rapid increase in the number of degrees awarded in computer science. (See figure 3-13.)

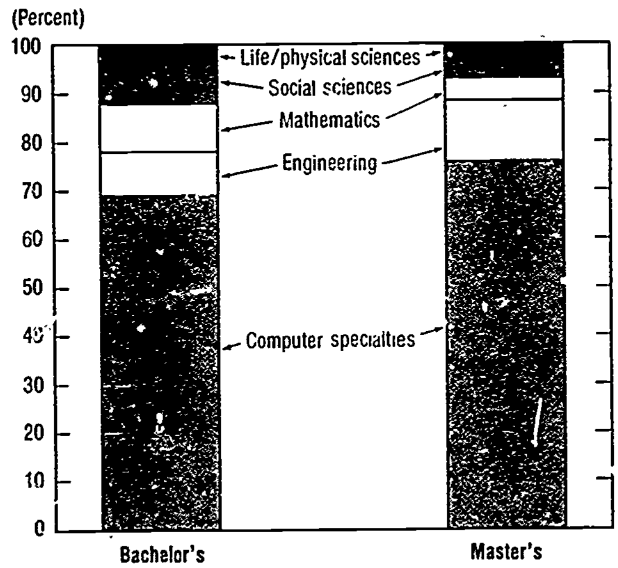
[24]NSF (1988a).

Figure 3-12.
**Percent of recent science/engineering (S/E) degree recipients employed in S/E jobs: 1976, 1986**




See appendix table 3-9. Science & Engineering Indicators — 1987

Figure 3-13.
**Degree field of 1984 and 1985 science/engineering graduates working as computer specialists in 1986**




See appendix table 3-10. Science & Engineering Indicators — 1987

Industry continued to be the major source of employment opportunities for new S/E graduates in 1986, providing jobs for 66 percent of those with bachelor's degrees and 56 percent of those with master's degrees. Educational institutions employed only 7 percent of the bachelor's and 15 percent of the master's, while the government sector (Federal, State, and local) accounted for between 12 and 16 percent of each group. Individuals with degrees (both levels) in the physical sciences, mathematics, engineering, and computer science were more likely to be working in industry; recipients of degrees in other fields were more evenly distributed among the employment sectors.

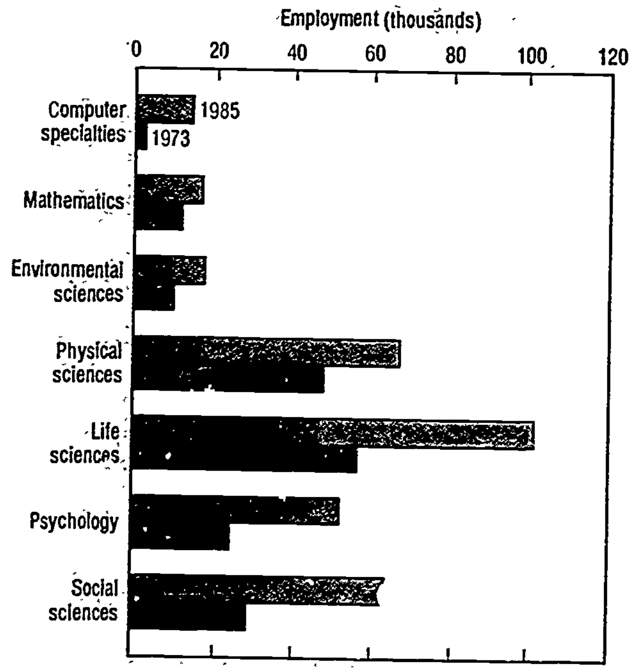
### Doctorates

In 1985, employed science and engineering doctorate holders in the United States numbered more than 400,000; this represented an increase of 82 percent since 1973. The proportion of S/E doctorate holders employed in non-S/E jobs increased steadily during this period, from 6 percent in 1973 to 8 percent in 1985.

Increases in employment among doctoral scientists and engineers varied substantially among fields between 1973 and 1985. (See figure 3-14.) Employment of computer specialists increased by an average of 15.4 percent per year during this period, by contrast, overall employment of Ph.D. scientists and engineers increased at a rate of 5.1 percent. Physical and mathematical scientists showed much slower growth rates (2.8 percent per year each). Employment of social scientists increased by 6.7 percent per year, primarily because of rapid growth in a number of relatively small social science fields including—for example—communications, political science, and public policy and administration.

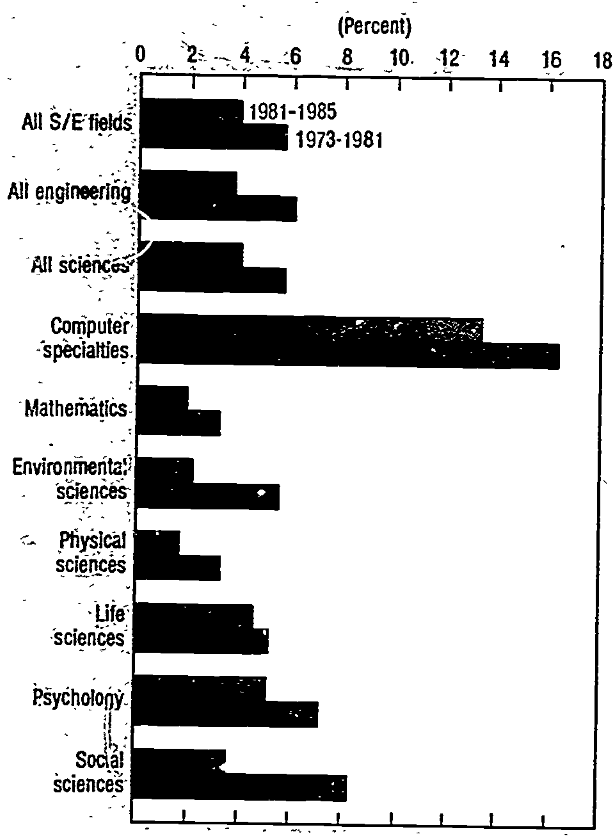
Employment growth of science and engineering doctorate holders has not been uniform. Engineering employment increased at a slightly faster rate than for scientists (6.0 percent versus 5.7 percent per year) between 1973 and 1981. Since 1981, however, employment growth in most S/E doctorate fields has slowed, with employment of Ph.D. scientists increasing at an average rate of 3.9 percent per year compared to 3.7 percent per year for doctoral engineers. (See figures 3-15 and 3-16.)

Figure 3-14.
**Doctorates employed in science, by field: 1973, 1985**




See appendix table 3-11. Science & Engineering Indicators — 1987

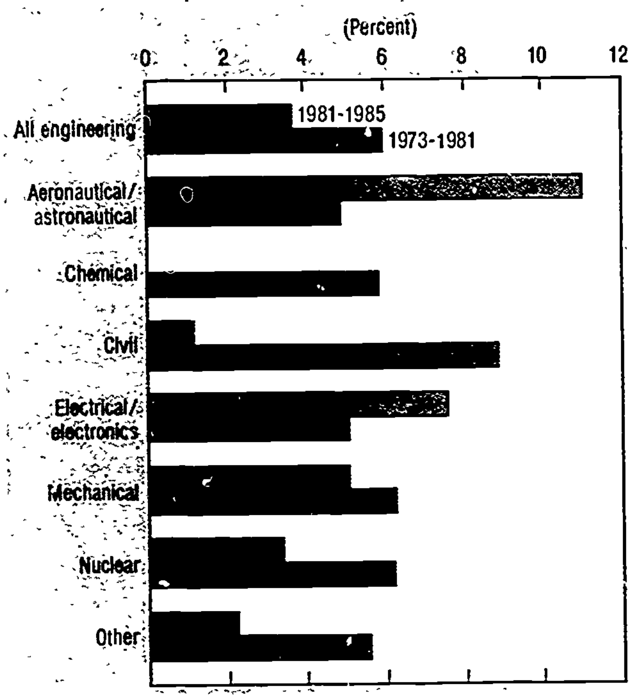
Figure 3-15.
**Annual percentage growth of doctorates employed as scientists by field: 1973-1981 and 1981-1985**




See appendix table 3-11. Science & Engineering Indicators — 1987

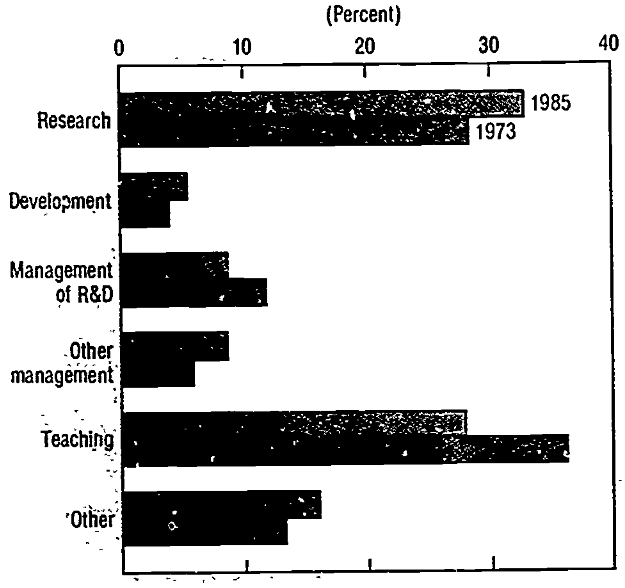
A trend toward nonacademic employment of S/E doctorate holders began in the early 1970's. Between 1973 and 1985, employment of doctoral scientists and engineers in industry increased more than twice that in the other sectors—142 percent versus 64 percent. Employment of S/E doctorate holders in business and industry continued to increase sharply between 1981 and 1985, at an annual rate of 6.1 percent versus 2.9 percent for all other sectors combined. The educational sector—although continuing as the primary employer of doctoral scientists and engineers—showed an increase in doctoral S/E employment of only 3.2 percent per year between 1981 and 1985. The share of doctoral scientists and engi-

Figure 3-16.
**Annual percentage growth of doctorates employed as engineers by field: 1973-1981 and 1981-1985**




See appendix table 3-11. Science & Engineering Indicators — 1987

Figure 3-17.
**Work activities of employed doctoral scientists and engineers: 1973 and 1985**




See appendix table 3-12. Science & Engineering Indicators — 1987

neers employed by business and industry, as compared with total employment of Ph.D. scientists and engineers, thus increased from 24 percent in 1973 to almost 32 percent in 1985. The slow growth rate of doctoral S/E employment in the academic sector during this period contributed to a reduction in its share of doctoral employment, from 59 percent in 1973 to less than 53 percent in 1985.

Between 1981 and 1985, industry employment of doctoral engineers increased at a slightly slower pace than in the academic sector (4.5 percent versus 4.8 percent per year), reversing the trends observed between 1973 and 1981. In contrast, Ph.D. scientist employment increased at an annual rate of more than 7 percent per year in industry between 1981 and 1985, but by only 3 percent per year in the academic sector.

The sectoral shifts in S/E Ph.D. employment between 1973 and 1985 were accompanied by a change in work activity patterns. During this period, for example, the proportion of doctoral scientists and engineers reporting teaching as their primary activity declined from 36 percent to 28 percent; this directly correlates to the shift to nonacademic employment. Management also declined in relative importance, decreasing from 21 percent to 17 percent. R&D activities remained stable, while a sharp increase occurred in activities related to such industrial applications as sales, production, and quality control. These activities accounted for 19 percent of the S/E doctoral workforce in 1985, up from 9 percent in 1973. (See figure 3-17.)

## WOMEN IN SCIENCE AND ENGINEERING

Although women have made substantial gains in science and engineering employment over the last decade, they remained underrepresented in the S/E workforce in 1986. However, the 526,700 women scientists and engineers then employed represented about 13 percent of all scientists and engineers, up from 8 percent in 1976. On the other hand, women now constitute almost one-half of overall U.S. employment. These proportions reflect the fact that, historically, women's participation in precollege science and mathematics courses and in undergraduate and graduate S/E education is below that of men. The underrepresentation of women varies between scientists and engineers: they accounted for almost 26 percent of scientists, but only 4 percent of engineers in 1986.

Although there has been dramatic growth in the employment of women scientists and engineers, they are still more likely than men to be both unemployed and underemployed. The unemployment rate for women scientists and engineers in 1986 (2.7 percent) was double the rate for men (1.3 percent). Women were also about three times as likely as men to report that they were underemployed (6 percent versus 2 percent); that is, working part-time when full-time work is preferred, or working involuntarily in a non-S/E job.

Regardless of field, women scientists and engineers are less likely than men to be employed in industry or in the Federal Government. They are, however, more likely than men to work in State and local governments, nonprofit organizations, and academic institutions. Because of the more rapid increase in the employment of women, they are generally younger than their male colleagues and have fewer years of professional experience. In 1986, about three-fifths of the women and one-fourth of the men reported fewer than 10 years of professional experience.[25]

Years of experience may affect several labor market variables. For example, women scientists and engineers in industry are less likely than men to hold management positions; in academia, they are less likely than men to hold tenure or be in tenure-track positions. However, women hold assistant professorships and nonfaculty positions more than twice as often as men—this is about the same proportion as in 1977.[26]

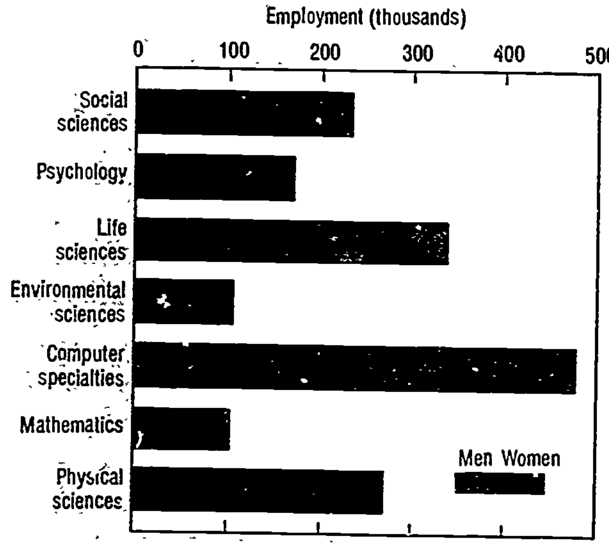
Women scientists and engineers also report salaries below those for men, with the smallest difference among those with less than 10 years' experience.[27] In fact, the average salaries earned by new S/E graduates are now about the same for both sexes in all fields.[28] The lower average salaries of women scientists and engineers with more than 10 years' work experience presumably reflect fewer opportunities for advancement.[29]

Women's S/E participation varies considerably by field. For example, among scientists, women represented 42 percent of all psychologists in 1986, but only about 13 percent of physical and environmental scientists. (See figures O-12 in Overview and 3-18.)

Since the mid-1970's, however, the field distribution of employed women scientists and engineers has changed, reflecting differing growth patterns across S/E fields. The most notable changes were observed for computer specialists, engineers, and social scientists. Between 1976 and 1986, employment of women computer specialists increased more than sixfold (from 21,000 to 128,000); by 1986, 24 percent of women scientists and engineers were computer specialists, up from 12 percent in 1976. The number of women in engineering quadrupled, growing at an average annual rate of almost 16 percent per year; moreover, the proportion of women in S/E who are engineers rose from 11 percent to almost 18 percent. During the 1976-86 period, employment of women social scientists increased by 65 percent, much less than the overall growth of women in all S/E fields. As a result of this slow growth, the proportion who were social scientists declined from 31 percent to 18 percent. (See figure O-13 in Overview.)

Employment of doctoral women more than tripled between 1973 and 1985. The fields with the greatest relative growth of women doctorate holders were engineering—

Figure 3-18.
**Employed scientists, by field and gender: 1986**




See appendix table 3-1. Science & Engineering Indicators — 1987

in which employment of women increased from 100 in 1973 to 1,500 in 1985—and computer specialties—in which employment increased from 100 to 1,600 during the same period. Despite rapid growth in these fields, only about 5 to 6 percent of the women holding doctorates were computer specialists or engineers in 1985. More than 80 percent of the increase in the employment of women doctoral scientists and engineers took place in three major fields: life sciences, social sciences, and psychology. The field distribution of women with doctorates, however, did not change greatly over the 1973-85 period: women were somewhat more likely to be social scientists or computer specialists and less likely to be mathematical or physical scientists in 1985 than in 1973. (See figure 3-19.)

Despite the continuing disparity in academic rank, salary levels, and unemployment rates, women scientists and engineers have made important strides in increasing their participation at every degree level and in every field and employment sector. Moreover, an increasing proportion of precollege women are taking high school courses in science and mathematics that are essential in electing to pursue a science career.[30]

The past 10 years have seen an especially dramatic increase in the number of women enrolling in and graduating from engineering schools. In 1983, women represented approximately one-fifth (17.0 percent) of the beginning engineering students nationally, as compared to 4.6 percent in the early 1970's.[31] High school guidance

[25]NSF (1988c).
[26]Vetter (1987), p. 7.
[27]NSF (1988c).
[28]NSF (1988a).
[29]NSF (1988c).

[30] Vetter (1987), p. 8.
[31]Jagacinski and L. old (1985), p. 204.



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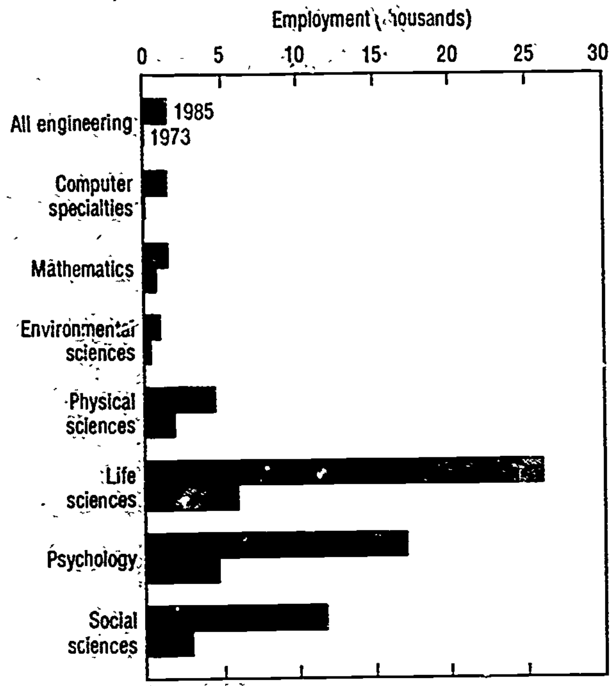
Figure 3-19.
**Women doctorates in science and engineering jobs by field: 1973 and 1985**




See appendix table 3-11.    Science & Engineering Indicators — 1987

counselors today are much more likely to suggest an engineering career for a female student; the most popular career guidance instrument—the Strong-Campbell Interest Inventory—now includes among its career scales both male and female engineer scales. In addition, many colleges and universities sponsor programs to recruit talented female high school students for engineering careers.[32]

## MINORITIES IN SCIENCE AND ENGINEERING

Over the last decade, minority groups in the United States have achieved substantial gains within the science and engineering workforce. The number of blacks, Asians, Hispanics, and native Americans employed as scientists and engineers has more than doubled since 1976, increasing faster than white S/E employment (110 percent versus 82 percent). Of the 363,000 minority scientists and engineers working in 1986, more than one-half (199,000) were Asian, while about 5 percent (18,700) were native American.[33] Blacks and Hispanics[34] represented about one-fourth (87,900 and 74,900) of the minority S/E workforce, respectively. (See figure O-14 in Overview.)

[32]Jagacinski, Linden, and Lebold (1985), p. 23.
[33]NSF (1988c)
[34]Includes members of all racial groups.

Blacks and Hispanics have historically been underrepresented in the science and engineering workforce, while Asians have been strongly attracted to these careers and native Americans have held a proportionate share. In 1986, blacks accounted for only 2.5 percent of employed scientists and engineers. In contrast, they represented 10 percent of total U.S. employment and almost 6 percent of those employed in the professional and related workforce. Asians, on the other hand, represented less than 2 percent of the U.S. labor force, but almost 6 percent of all scientists and engineers. In the same year, Hispanics represented about 2.1 percent of employed scientists and engineers, while comprising 5.0 percent of all employed persons. Native American scientists and engineers represented somewhat less than 1 percent of total S/E employment; this was roughly equivalent to their participation in the overall U.S labor force.

S/E field representation varied significantly among the racial/ethnic groups. Asians were the least likely to be employed in the environmental and behavioral sciences, while blacks were generally more likely to work as social scientists and life scientists. The proportions who were engineers in 1986 ranged from 42 percent of the blacks to 64 percent of the Asians. In comparison, 59 percent of the whites were engineers. Since 1976, blacks have moved away from engineering and toward the social sciences and computer specialties; among Asians, proportional increases have occurred in engineering and computer specialties.

Black and native American scientists and engineers were as likely as whites (29 percent) to hold management positions in 1986; in contrast, Asians (22 percent) and Hispanics (26 percent) were less likely to report management or administration as their primary work activity.[35,36] For those employed in educational institutions,[37] both blacks and Asians were less likely than whites to hold tenure or be in tenure-track positions. Native Americans were more likely to hold tenure or be in tenure-track positions than were whites, and Hispanics were almost as likely as all scientists and engineers to hold tenure or be in tenure-track positions.

Salaries earned by black and Hispanic scientists and engineers in 1986,[38] were, on average, below those earned by whites, Asians, and native Americans. While salaries for both Asians and native Americans were above those for their white colleagues in 1986, salaries for blacks averaged 81 percent of those for whites. Hispanics earned about 90 percent of the salaries paid across all racial/ethnic groups.

Generally, minorities in S/E are more likely than white scientists and engineers to be unemployed and underemployed, and less likely to work in S/E jobs.[39] For example, while the unemployment rate for whites in 1986 was 1.5 percent, unemployment among black and Asian scientists and engineers averaged around 2.8 percent. Only

[35]Percentages include scientists and engineers employed in non-S/E activities.
[36]NSF (1988c).
[37]Ibid.
[38]Ibid.
[39]Ibid.

2.4 percent of the Asians reported that they were underemployed in 1986, compared to 2.5 percent of the whites; however, 5.5 percent of the blacks reported underemployment. The proportions of employed scientists and engineers working in S/E fields ranged from 79 percent of the native Americans to 77 percent of the blacks and 88 percent of the Asians.

While minority participation in the science and engineering workforce has risen steadily since 1976, increasingly greater numbers of S/E graduates from these groups may be required over the next decade.[40] While the general college-age population is predicted to decline in the 1990's, the proportion of blacks, Hispanics, Asians, and native Americans in the 18- to 24-year-old age group is expected to increase. The role of minority groups in the S/E workforce could thus expand significantly.

## SUPPLY AND DEMAND FOR S/E PERSONNEL—LABOR MARKET INDICATORS

Demographic statistics on S/E employment trends alone do not indicate whether the current supply is sufficient to meet the economy's needs. Recent concerns over shortages of engineers and computer specialists and about suitable job opportunities for some scientists suggest a potential maldistribution in the S/E labor market and a need for indicators to assess supply and demand conditions. Standard labor market indicators of supply and demand conditions include labor force participation and unemployment rates. The S/E utilization rate also helps in assessing both the market for science and engineering jobs and the extent to which those with S/E training are utilizing their skills. While no single statistic can provide a firm basis for measuring shortages or surpluses of scientists and engineers, some statistics—when analyzed together—allow a meaningful inference about the S/E labor market condition.

### Labor Force Participation Rates

The S/E labor force includes scientists and engineers who are employed—either in or outside of science and engineering—and those who are unemployed but seeking employment. In 1986, approximately 95 percent of the S/E population were in the labor force, with scientists and engineers equally likely to be working or seeking employment. Participation rates were about equal for men and women (95 percent versus 94 percent), with only a slight variation among major fields.

### Unemployment Rates

A standard measure of labor market conditions is the unemployment rate, which measures the proportion of those in the workforce who are not employed but seeking work. In the last decade, scientists and engineers have been steadily improving their labor market position, outperforming both the general labor force and all professional and related workers. In 1976, the unemployment rate for scientists and engineers was 3.0 percent compared to 3.2 percent for all professional and technical workers and 7.7 percent for the entire U.S. workforce. In 1986, these rates had fallen to 2.0 percent and 7.2 percent for all professional and technical workers and the total workforce. S/E unemployment fell at a faster rate, declining to 1.5 percent in 1986. (See figure 3-20.)

While almost all scientists and engineers who wanted jobs in 1986 were employed, the level of unemployment among the different S/E fields varied considerably. Environmental scientists posted the highest S/E unemployment rate at 4.4 percent; computer specialists experienced the lowest rate at 0.8 percent. Of engineering occupations, petroleum engineers showed the highest unemployment rate at 3.4 percent.

### S/E Employment Rate

The S/E employment rate measures the extent to which employed scientists or engineers have a job in science or engineering. Depending on the specific reasons for non-S/E employment, a low S/E employment rate could be an indicator of underutilization. Factors relating to non-S/E employment include lack of available S/E jobs, higher pay for non-S/E employment, location, or preference for a job outside of science or engineering.

In 1986, the S/E employment rate was 85 percent (down slightly from 91 percent in 1976), with the rate for engineers (92 percent) substantially above that for scientists (77 percent). S/E employment rates ranged within science fields from 61 percent in the social sciences and 78 percent in the computer specialties, to 87 percent in the environmental and physical sciences. The relatively low S/E employment rate for computer specialists suggests that a substantial number may be applying their skills to commercial activities rather than to more traditional S/E activities such as research and development.

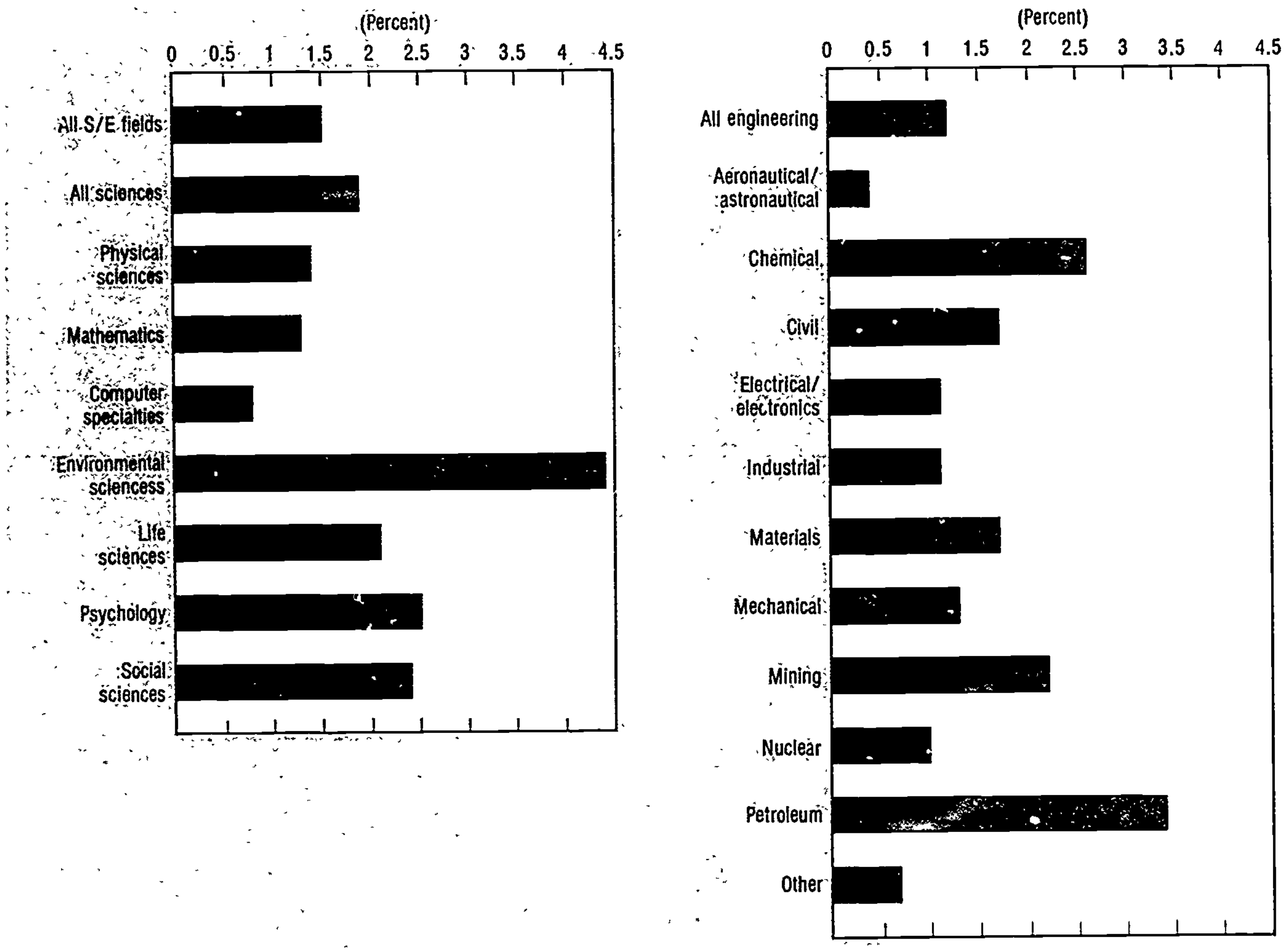
### S/E Underemployment

Although unemployment rates of scientists and engineers are relatively low compared with rates for the general population, those who are employed may be underemployed. Working in a non-S/E job or working part-time may indicate underemployment, depending on the reasons for such employment. To help measure the extent of potential underemployment, the S/E underemployment rate was developed. This rate is defined as those who are involuntarily working in non-S/E jobs or involuntarily working part-time as a percent of total employment.

The underemployment rate for scientists and engineers in 1986 was 2.6 percent, with scientists much more likely than engineers to be underemployed (4.3 percent versus 1.0 percent). Among scientists, social scientists and psychologists (7.2 percent and 5.7 percent) are more likely than physical scientists and computer specialists (1.9 percent and 2.5 percent) to be underemployed. Underemployment among engineers ranged from 0.4 percent for nuclear engineers to 2.0 percent for mining engineers.

[40] Finkbeiner (1987), p. 17.

Figure 3-20:
**S/E unemployment rates by field: 1986**




See appendix table 3-13.

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### S/E Underutilization

To derive a more comprehensive indicator of potential underutilization, figures for those who are unemployed and those who are underemployed may be combined and expressed as a percent of the labor force. In 1986, the derived underutilization rate for scientists and engineers was 4.1 percent. The rate for scientists (6.1 percent) was almost three times that for engineers (2.2 percent); among scientists, the highest underutilization rates were reported for environmental scientists and social scientists (roughly 10 percent each). Petroleum and chemical engineers posted the highest rates among engineering occupations, at about 5 percent each.[41] (See figure 3-21.)

### Shortages of S/E Personnel

Employer success in meeting staffing requirements is another direct indicator of S/E supply and demand labor market imbalances. In 1985, relatively few industrial employers reported shortages of scientists and engineers. The only fields with as much as 15 percent of their employers reporting shortages were electronics engineering, nuclear engineering, and electrical engineering.[42] This is in marked contrast to the labor market of 1981, when one-half or more of most engineering and computer specialties field employers reported shortages.[43]

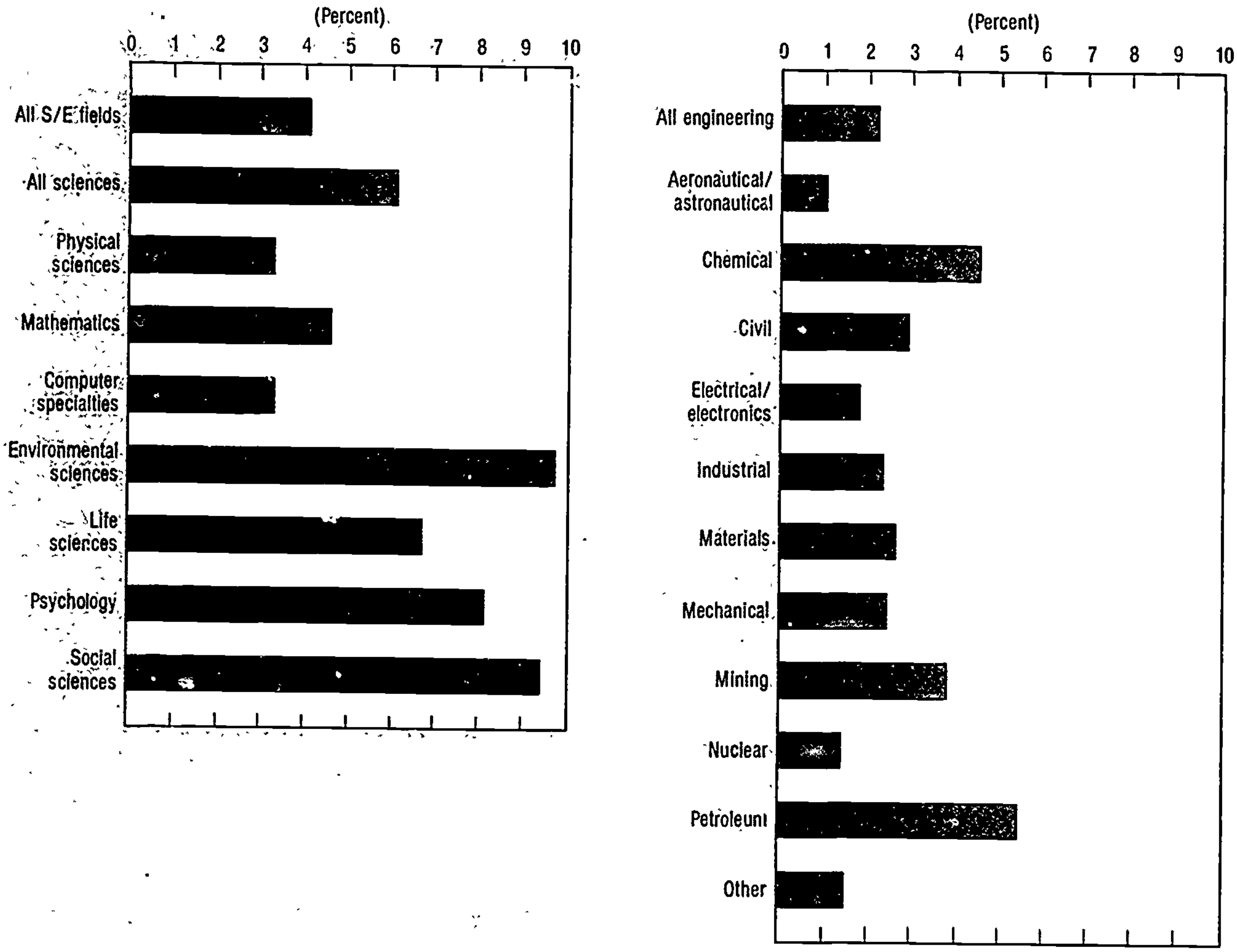
Engineering schools in the U.S. have reported what may be considered serious and persistent shortages of faculty. In 1986, almost 9 percent of authorized full-time engineering faculty positions were unfilled; moreover,

[41]The underutilization rate as derived here is only a partial measure, since it does not take into account the number of scientists and engineers who may have jobs requiring skills below those they actually possess.

[42]Market Facts, Inc. (1986), p. 3.

[43]NSF (1982).

Figure 3-21.
**S/E underutilization rates by field: 1986**




See appendix tal‾ 3-13.

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many institutions stated that the authorized levels would be higher if it were possible to fill such positions.[44] Engineering faculty shortages are grounded in the long-term decline in engineering doctorates awarded to U.S. citizens (see the discussion below on the S/E pipeline) and increasing demand for engineering Ph.D. holders in the industrial sector. (See the previous section on doctorates.)

## Overview

The employment indicators discussed above suggest that the labor market situation for scientists and engineers has been favorable. It can, for example, be inferred from the relatively high S/E participation rates and low S/E unemployment rates that in 1986 there was generally sufficient demand to accommodate th S/E labor force. In addition, the low levels of shortages reported by industrial employers in 1985 would indicate that the S/E labor force is in general—with the single exception of engineering Ph.D.'s—nearly sufficient to meet the economy's current demands. For now, there appears to be a rough balance between supply and demand for science and engineering personnel.

The positive balance between supply and demand for S/E personnel has been accomplished, however, through means other than new S/E graduates with fully appropriate training in their occupational fields. Substantial occupational mobility (with attendant possible quality costs[45]) and increasing reliance on foreign-origin personnel (native-born U.S. citizens declined from 90 percent of the S/E labor force in 1972 to 83 percent in 1982[46]) have

[44]NSF (1988b).

[45]Dauffenbach and Finn (1984).
[46]NSF (1986a), p. 39.

been largely responsible for the supply/demand equilibrium in the science and engineering labor market.

## PROJECTED DEMAND

### Short-Term Outlook

Overall 1986 labor market conditions for scientists and engineers indicate favorable job prospects for the remainder of the 1980's, however, recent events, as outlined below, may severely affect the number of anticipated employment opportunities in certain fields and industries.

The drastic drop in the price of crude oil to under $10 a barrel in 1986—and the subsequent closing of numerous oil refineries and related production facilities—has had a profound effect on petroleum-related S/E employment. In 1982, nearly 7,000 students at four major southwest universities—University of Oklahoma, Texas A&M University, University of Texas, and Louisiana State University—were pursuing studies in petroleum engineering, geology, and geophysics. Since that time, however, the number of students majoring in these fields has declined annually.[47] Professors at each school have expressed concern that the fall of 1986 will mirror the fall of 1982—and that, just as the supply of graduates in 1986 exceeds demand, too few will graduate in 1990 to meet what many experts predict will be heightened demand 4 years hence.[48]

Electrical/electronics graduates are also expected to experience short-term difficulty in finding employment with high-tech companies.[49] Between 1985 and 1986, the electronics industry recorded a 3.4-percent drop in total employment, representing a decline of about 75,000 jobs during the year.[50] Component companies, particularly hit hard in 1986, lost 33,000 jobs or 5.0 percent of their workforce, computer manufacturers saw their employment ranks dwindle by 7.4 percent to 418,000. On the other end of the spectrum, however, the software/programming sector recorded sizable gains in employment, up 20,500 jobs (a 10.4-percent increase) between 1985 and 1986.

Engineering students in 1987 were expected to find fewer jobs and less opportunity when they graduated. Between July 1986 and July 1987, the College Placement Council reported a significant drop in the number of offers to new bachelor's degree recipients in engineering.[51] In addition, a recent poll of 761 employers found a slight tapering off in overall demand. However, the outlook for computer science, mathematical science and electrical/electronics engineering graduates was still the highest in terms of supply/demand ratios.[52]

### Long-Term Outlook

Looking ahead to the year 2000, high-technology industry growth and the increasing use of high-technology goods and services in the economy as a whole will lead to the increasing employment of science, engineering, and technical personnel in industry.[53] The Bureau of Labor Statistics (BLS) estimates that the net increase in all new jobs (technical and nontechnical combined) created between 1986 and 2000 will be in service-producing industries. Goods-producing industries, in contrast, are projected to show virtually no net change in overall employment levels, as projected increases in construction will be offset by employment declines in mining and manufacturing.

The computer and data processing industry is projected to be the fastest growing of all industries in the economy,[54] providing the greatest number of employment opportunities for science, engineering, and technical personnel. Underlying this development are the continued shift toward contracting out various firm operations and the growth in demand for computer software and other types of modern business services. Most of the growth within this industry is likely to occur in programming and software services. The investment boom in high-technology products such as computer-aided design/computer-aided manufacturing (CAD/CAM) and robotic production techniques projected to occur in the 1990's[55] will require significant increases in new software development, especially in high-level programming languages.

While overall employment growth is expected to decline within the manufacturing sector through the end of the century, the changes in workforce composition that occurred over the previous decade are expected to continue into the 1990's. Although projected to show only moderate employment increases, the computer production and semiconductor industries are nevertheless predicted to be among the leaders in output growth through the 1990's, increasing at 7.4 and 5.8 percent[56] per year, respectively, compared to only 2.4 percent annually for GNP.[57] This expected growth will necessitate an increasingly greater emphasis on "knowledge" skills, with the proportion of labor-intensive workers continuing to decline.

College and university faculty are expected to decline overall in the 1990's in response to an expected decrease in total college enrollments, this in turn will stem from a drop in the traditional college-age population. This decline, in addition to expected low retirements of current faculty,[58] may adversely affect academic job prospects in the near future for scientists. Possible increases in the proportions of college students enrolling in science programs could alleviate this situation. (See discussion on supply, below.) On the other hand, engineering faculty

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[47] Commission on Professionals in Science and Technology (1986), p. 4.
[48] Ibid.
[49] American Electronics Association, as reported in Commission on Professionals in Science and Technology (1986), p. 5.
[50] U.S. Department of Labor, Bureau of Labor Statistics (1987), pp. 68, 77, 203.
[51] College Placement Council Salary Survey (1987).
[52] Shingleton and Scheetz (1986), p. 15.

[53] Silvestri and Lukasiewicz (1987), p. 47
[54] Personick (1987), p. 39.
[55] Ibid.
[56] Ibid., p. 34.
[57] Kutscher (1987), p. 4.
[58] Finn (1986).

shortages have been persistent, primarily because of a notable drop (compared to the 1970's) in the number of American citizens who obtained Ph.D.'s in engineering, and an increasing proportion of Ph.D. engineers opting for employment in private industry.

The employment opportunities for scientists, engineers, and technicians are projected to increase substantially between 1986 and 2000, rising by approximately 36 percent, compared to 19 percent for all occupations. This growth will vary dramatically among fields, however; computer specialists are expected to experience the largest employment increase and drafters the smallest. (See table 3-1.)

**Table 3-1. Projected increase in demand between 1986 and 2000 for scientists, engineers and technicians (SET's), by field**

| Field | Percent |
|---|---|
| Total SET fields | 36 |
| Total scientists | 45 |
| Computer specialists | 76 |
| Life | 2[illegible] |
| Mathematical | 29 |
| Physical | 13 |
| Social | 36 |
| Total engineers | 32 |
| Aeronautical/astronautical | 11 |
| Chemical | 15 |
| Civil | 25 |
| Electrical/electronics | 48 |
| Industrial | 30 |
| Mechanical | 33 |
| Other | 24 |
| Total technicians | 36 |
| Computer programmers | 70 |
| Drafters | 2 |
| Electrical/electronics | 46 |
| Other engineering | 26 |
| Physical, mathematical and life sciences | 15 |

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *BLS Monthly Labor Review* (September 1987), pp. 51-52

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Engineering employment is expected to increase 32 percent between 1986 and 2000. Much of this increase will occur among electrical/electronics engineers engaged in developing computers, communications equipment, and defense-related electronic equipment. Mechanical and civil engineering employment are also expected to grow rapidly during this period. Mechanical engineers will be needed to keep product design and production methods up to date in support of industry's desire to remain competitive. Civil engineers will be needed for additional heavy construction.

Among science occupations, employment of mathematical scientists is projected to grow by 29 percent between 1986 and 2000, primarily because of increased statistical work and mathematical modeling. Chemists, on the other hand, are expected to increase by only 11 percent, reflecting the massive corporate restructuring of the chemicals industry in 1984-85.[9]

As stated above, the highest employment growth among all S/E occupations is projected to be in computer specialties. The continued expansion of computer and data processing-related services industries will be accompanied by an increasingly greater demand for computer specialty skills; the number of computer specialists engaged in developing and operating computer based systems is projected to increase by 76 percent between 1986 and 2000.

S/E technicians are projected to increase 23 percent between 1986 and 2000 in direct correlation to the employment trends of corresponding science and engineering occupations. (See table 3-1.) Computer programmers are expected to increase by 70 percent during this period, keeping pace with computer specialists. However, different rates of change are expected for the various other specialties, given the changing demographics of the college-age population and other factors affecting employment rate growth/decline within the education sector.

## S/E SUPPLY OUTLOOK

### The S/E Pipeline

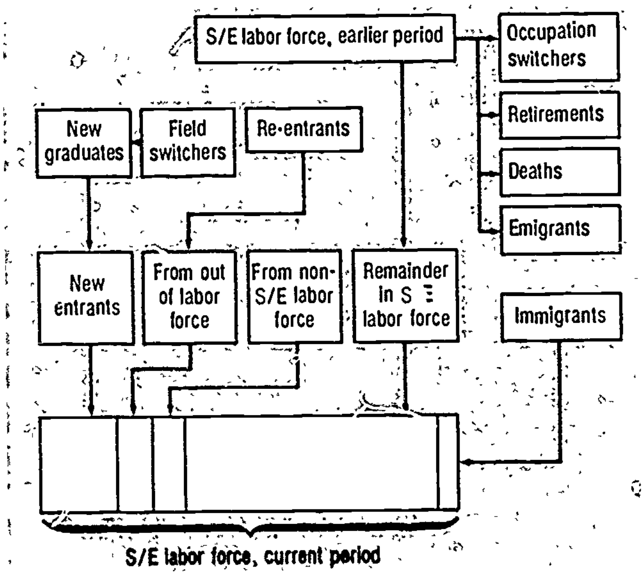
The flows of S/E workers in and out of the labor force generally serve as equilibrating marketplace forces bringing supply and demand into balance. Such flows signal future supply conditions for use by persons making career plans, handling recruiting activities, planning academic programs, or developing Federal policies on science and technology. There are three direct sources of flows into and out of the science and engineering workforce—new graduate entrants, occupational mobility, and separations from the labor force. The bulk of supply changes in the S/E labor market are formed by these movements. (See figure 3-22.)

*New Entrants.* New S/E graduates at the bachelor's, master's, and doctorate degree levels provide the basic inflow into the science and engineering workforce. However, the number earning S/E degrees—especially at the undergraduate level—is not identical to the supply of new S/E workers. For instance, new S/E bachelor's recipients may choose to pursue graduate education, which may be a prerequisite for employment in some fields, rather than immediately enter the labor force. In addition, some S/E baccalaureates may enter non-S/E occupations, or may work part-time while pu ing graduate education on a part-time basis.

In 1986, about 20 percent of recent S/E bachelor's degree recipients were enrolled in full time graduate studies while an additional 11 percent were enrolled on a part-time basis; corresponding rates of 21 percent and 9 percent were observed among master's degree recip-

[9] American Chemical Society (1986), p. 23.

Figure 3-22.
**S/E labor market flows**




Note: The sizes of the boxes do not represent actual values.

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ients.[60] Analysis by field shows that labor force demand inversely affected graduate school enrollment rates. For example, relatively low full-time enrollment rates of 5 percent to 17 percent were observed in such high-demand fields as engineering, mathematics, and computer science; rates of 21 percent to 39 percent were observed in fields showing lower demand, such as the social sciences and physical sciences.

*Occupational Mobility.* Experienced workers constitute the second category of personnel affecting overall S/E supply. These workers provide a short-term flexibility to the S/E supply system that cannot be met through recent college graduates. The mobility of these workers is determined primarily by job opportunities across various occupations as well as by occupation-specific characteristics.

The ability of the S/E labor market to respond to unanticipated surges in demand was severely tested over the last decade by the semiconductor and computer industries. The initial increase in requirements for people trained in engineering and computer science far exceeded the expected number of new graduates in these fields. For a short-term remedy, employers relied on the successful importation of scientific and technical talent from related fields.[61] The long-term response to the continuing demand has been increased employer training of current engineering[62] and computer personnel as well as a rise in the number of new S/E graduates in these fields.

[60]NSF (1988a).
[61]U.S. Congress, Office of Technology Assessment (1985), p 6
[62]Dauffenbach and Finn (1984).

*Separations.* The available supply of S/E personnel is reduced by deaths and retirements While separation rates depend partially on age distribution and life expectancy, potentially more immediate and significant effects on attrition could come from changes in the length of time people choose to remain in the S/E labor force. Such economic conditions as rising inflation rates (affecting a pension's purchasing power) and the abolishment of compulsory retirement policies are only two of the factors that could lead to postponing retirement. It is difficult to assess the net effect of these factors on future S/E separation rates.

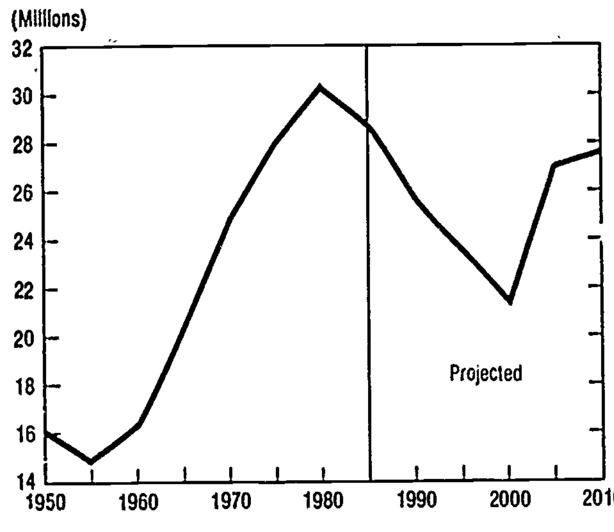
## Outlook

In the 1990's, changing demographics may impose restraints on the supply of newly trained scientists and engineers. The smaller birth cohorts of the early 1970's will definitely reduce the size of the traditional college-age population and could possibly reduce college enrollments. In fact, with the population of 18- to 24-year-olds expected to decline by 23 percent between 1980 and 1995[63] (see figure 3-23) college enrollments could decrease by as much as 12 to 16 percent by 1995 [64] Additionally, the first waves of the baby boom population that entered the labor force in the 1960's will begin to retire These two combined forces may hinder workforce ability to meet demand increases over the next decade.

On the other hand, a declining college-age population does not necessarily mean a corresponding decline in the

[63]Kutscher (1987), p. 4.
[64]National Research Council, Commission on Human Resources (1979), pp. 12-15, and Bowen (1981), pp. 11-15.

Figure 3-23.
**18-24 year olds in the U.S. population, 1950-2010**




See appendix table 3-14.

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number of new S/E entrants to the labor force. The enrollment gap may be filled to a certain extent by increased participation of older students and foreigners; many of these latter remain in the U.S. to work. Also, small shifts in the percentages of students choosing to train in S/E fields and of graduates who choose to enter S/E employment fields could change limited supplies of new entrants into considerably larger numbers; these shifts would thus eliminate labor market shortages of scientists and engineers.[65] Similar upward adjustments in the proportion of college students enrolling in science and engineering could also affect the demand for S/E doctorate holders to fill faculty positions.

The magnitude of these possible adjustments is uncertain. Past experience would indicate that the labor markets have sufficient flexibility to respond, however, forward projections are much more problematic. For example, although it is known that older students are a rising proportion of all undergraduates, it is uncertain how many of them will enter S/E employment fields. Also, while it is believed that adjustments in enrollment patterns will be made in response to a growing demand for S/E graduates, it is not clear that such adjustments will be sufficient to provide an adequate supply.

There are other adjustments that could occur. Labor force mobility is particularly important in tight market situations where both newly trained S/E entrants and experienced S/E personnel may be induced to leave their current fields of specialization and transfer into higher demand fields. (This is what occurred to satisfy the very high growth in demand for computer specialists.) There may also be delays in S/E worker retirements in response to needs for their services; this has been the case in past serious engineering shortages. Employers may also provide training and upgrading of technician personnel.

Widespread postponement of retirements and promotion of technicians into professional positions could, however, adversely affect the quality and caliber of the S/E workforce. In academia, the "graying" of faculty and the inability of universities and colleges to recruit and hire new Ph.D. graduates may combine to create a less productive and non-research-oriented scientific academic community.[66] In industry, employer-trained technicians placed in professional positions will not provide the same degree of technical ability or occupational mobility as academically trained S/E personnel.[67]

## INTERNATIONAL EMPLOYMENT OF SCIENTISTS AND ENGINEERS

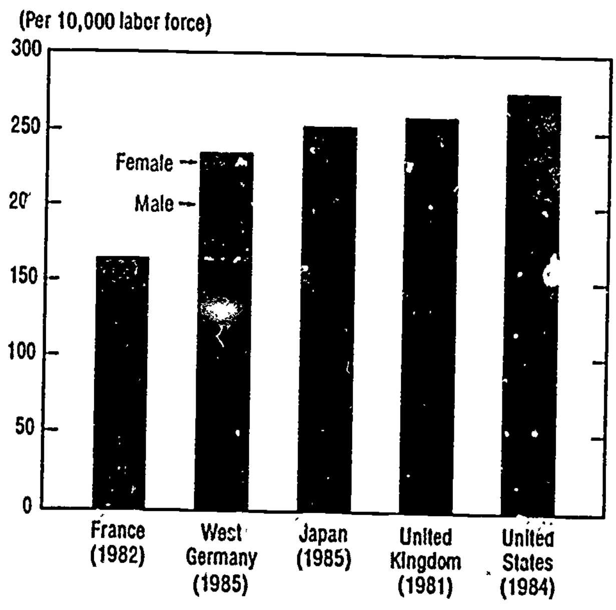
The employment of scientists and engineers is a significant indicator of the level of effort and relative national priorities for science and technology among major industrial countries. While there are always problems of international comparability given differences in data collection methods and data estimation, these employment data provide meaningful insight into the relative strengths of the S/E workforces of the United States and other countries.

In the early 1980's, the number of nonacademic scientists and engineers employed in the U.S. was about equal to the combined total of those in France, West Germany, Japan, and the United Kingdom. This result was not unexpected, however, because the total U.S. population is about the same as that of the other countries combined. When the number of scientists and engineers as a proportion of the total labor force is examined for each country, however, the outcome is somewhat different. Here, the United Kingdom, Japan and the United States employed almost the same percentage of scientists and engineers, with the United States employing slightly more than the others. (See figure 3-24.)

In all countries examined, service industries employed the largest proportion of scientists, while manufacturing industries predominated among employers of engineers.

In the United States and Japan, one-quarter of the scientists and engineers employed in manufacturing industries in the early 1980's were electrical/electronics engineers. Manufacturing industries in West Germany and France employed relatively more civil engineers than in the other countries, while the United Kingdom employed a relatively greater proportion of natural scientists. Japan had a much higher proportion of its scientists and engineers employed in service and construction industries, while U.S. scientists and engineers were more evenly divided between manufacturing/mining indus-

Figure 3-24.
**Non-academic scientists and engineers per 10,000 total labor force, for selected countries, by gender**




See appendix table 3-15.

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[65] Hansen (1986).
[66] Paula Stephan, as reported in Cunningham (1986), p. 6.
[67] Dauffenbach and Finn (1984).



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tries and service industries. In France, a very high percentage of S/E's worked in the government sector (See figures 3-25 and 3-26.)

The United States has the largest number—both in absolute terms and as a proportion of the labor force—of scientists and engineers working in R&D of any country except the Soviet Union. (See figures 3-27 and O-7 in Overview.) Other countries have, however, been closing the gap and now have concentrations of R&D scientists and engineers approximating that of the United States. In 1985, Japan's ratio per 10,000 (63.2) was very close to that of the U.S. (67.4).

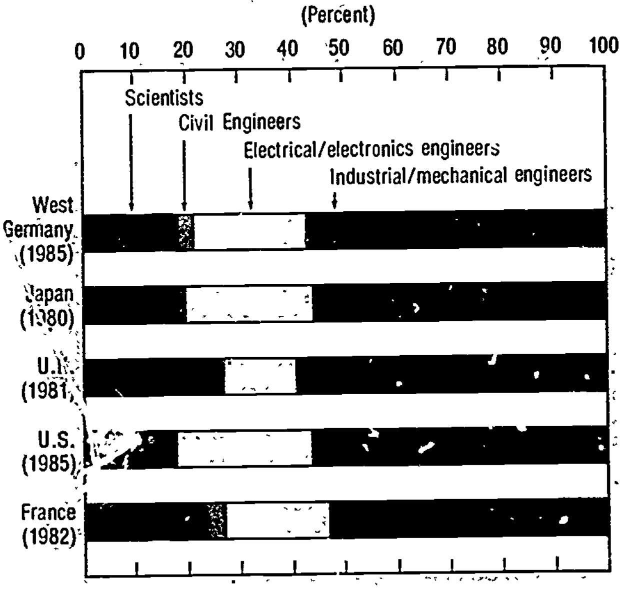
The United States was second to the United Kingdom in the number of scientists per 10,000 total labor force (101 versus 113 per 10,000) and third to West Germany in the number of engineers per 10,000 labor force (175 versus 194 per 10,000) in the mid-1980's. However, the U.S. ranked first among the countries compared in both the ratio of scientists and of engineers with university degrees.[68] In West Germany, most engineers have qualifications from technical colleges.[69] Of the reported S/E's in the United Kingdom, less than one-half has a university degree. Nonetheless, some of these countries may have stronger training in science and mathematics at the precollege level than has the U.S.

The United Kingdom, France, and West Germany all had greater concentration of first university degrees in the natural sciences in 1984/85 than did the United States (See figure O-8 in Overview.) In absolute numbers, however, there were more U.S. degree recipients. In 1982, Japan graduated more engineers at the bachelor's degree level than did the U.S., by 1985, however, the number of U.S. engineering graduates was 9 percent greater because of an increase in the number of U S graduates and a decline in Japanese engineering degrees The U.S. awards more than twice the number of engineering doctoral degrees and almost 10 times the number of natural science doctorates than does Japan.

The age of a country's S/E labor force can be an indicator of training recency and future capabilities. On average, women scientists and engineers were younger than their male counterparts in all countries. Japan had the youngest scientists and engineers of all five countries. In 1985, almost 50 percent of Japanese nonacademic scientists and engineers were under 35 years old, and only 7 percent were 55 or older. This supports recent observations on the high output of the Japanese educational system. Scientists and engineers, on average, had a higher median age in France than in the other countries. (See figure 3-28.)

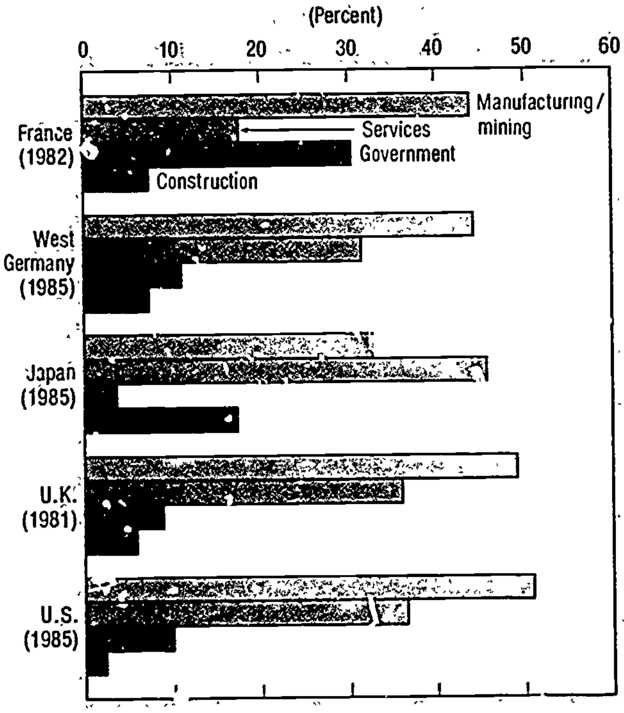
When all five countries were compared, the vast majority of engineers were men, with the small proportion of females slowly increasing. Science occupations were also predominantly male, but with a larger percentage of

Figure 3-25.
**Distribution of scientists and engineers in manufacturing for selected countries, by occupation group**




See appendix table 3-16. Science & Engineering Indicators — 1987

Figure 3-26.
**Distribution of scientists and engineers for selected countries, by sector**



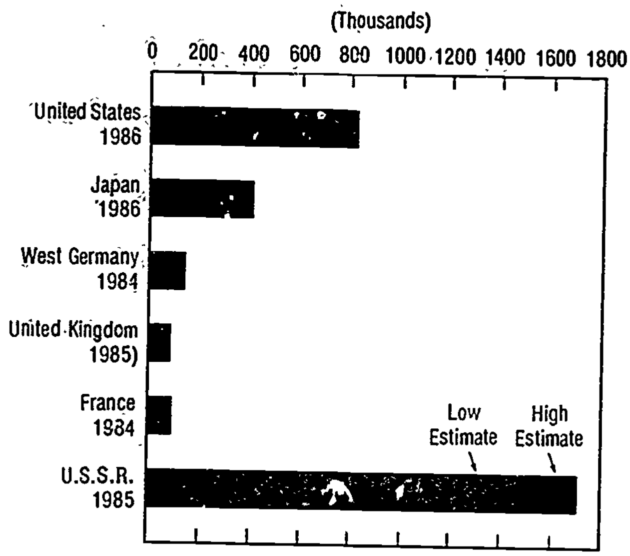

See appendix table 3-18. Science & Engineering Indicators — 1987

[68] Way and Jamison (1986), p. 2.

[69] For purposes of comparability, only engineers with university degrees are used. West German engineers trained in professional colleges generally have received more specialized and technically intensive training, while university degree recipients have received broader and more academic engineering training.

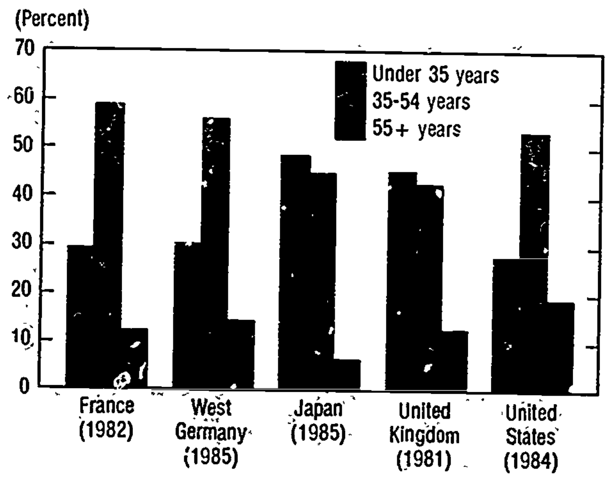
women represented. The United States and the United Kingdom had the best records for utilizing female scientists and engineers; only 6 percent of scientists and engineers in West Germany were women, and nearly one-half of these were social scientists. In Japan, engineers outnumbered scientists by almost 4 to 1. Women comprised only 5 percent of Japan's scientists and engineers; nearly one-half of these were computer specialists. In the United Kingdom, 4 out of 10 male scientists and engineers were industrial or mechanical engineers, the same proportion as in West Germany.

Figure 3-27.
**Scientists and engineers engaged in R&D for selected countries**




See appendix table 3-19. Science & Engineering Indicators — 1987

Figure 3-28.
**Distribution of scientists and engineers for selected countries, by age group**




See appendix table 3-20. Science & Engineering Indicators — 1987

## REFERENCES


American Chemical Society, "Unemployment Slightly Higher for Chemists in the Past Year," *Chemical and Engineering News*, June 30, 1986.

Bowen, W., *Report of the President* (Princeton: Princeton University, April 1981).

College Placement Council Salary Survey, *Formal Report No. 3, July 1987* (Bethlehem, PA: College Placement Council, 1987).

Commission on Professionals in Science and Technology, *Manpower Comments*, Vol. 23, No. 6, July-August 1986.

Council of Economic Advisors *Economic Report of the President* (Washington, DC: 1987).

Cunningham, R.T., "The Relationship between Age, Vintage and the Productivity of Scientists," *Research*, Georgia State University, Spring 1986.

Dauffenbach, R.C. and M.G. Finn, *Issue of Quality in the Engineering Work Force* (Oak Ridge, TN: Oak Ridge Associated Universities, December 1984).

Doigan, P., "ASEE Survey of Engineering Faculty and Graduate Students, Fall 1983," *Engineering Education* (October 1984).

Drucker, P.F., "The Changed World Economy," *Foreign Affairs*, Vol. 64, No. 4, 1986

Finkbeiner, A.K., "Demographics or Market Forces?," *Mosaic*, NSF 86-88, Vol. 18, No. 1, Spring 1987.

Finn, M.G., *Factors Affecting the Demand for Natural Scientists and Engineers in the United States, 1985-2010: A Review of Existing Knowledge* (Oak Ridge, TN: Oak Ridge Associated Universities, July 1986).

Hansen, W.L., "Salary Differences across Disciplines," *Academe*, July-August 1985.

Hansen, W.L., "The Impact of Demographic Trends on the Scientific and Engineering Work Force," testimony presented before the Science Policy Task Force, Committee on Science and Technology, U.S. House of Representatives, February 27, 1986.

Jagacinski, C.M., K.W. Linden, and W.K. LeBold, "Today's Women in Engineering," *U.S. Women Engineers*, July/August 1985.

Jagacinski, C.M. and W.K. LeBold, "Comparisons of Women and Men in the Engineering Workforce," *IEEE Transactions on Education*, Vol. E-28, No. 4, November 1985.

Kutscher, R.E., "Overview and implications of the projections to 2000," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

Market Facts, Inc., *1985 NSF Science and Engineering Labor Market Study* (Washington DC: April 1986).

National Research Council, Commission on Human Resources, *Research Excellence through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research* (Washington, DC: 1979).

National Science Foundation, "A decade's shift in industry science and engineering job patterns," *Mosaic*, NSF 87-34, Vol. 18, No. 3, Fall 1987a.

National Science Foundation, *Characteristics of Recent Science/Engineering Graduates: 1986* (Washington, DC: National Science Foundation, 1988a).

National Science Foundation, "Federal Scientists and Engineers: 1986," Science Resources Studies detailed tables (Washington, DC: National Science Foundation, 1987b).

National Science Foundation, *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*, NSF 86-305 (revised) (Washington, DC: National Science Foundation, 1986a).

National Science Foundation, "Labor Markets for New Science and Engineering Graduates in Private Industry," *Science Resources Studies Highlights*, NSF 82-310 (Washington, DC: National Science Foundation, 1982).

National Science Foundation, "Shortages Persist for Some Engineering Fields in Industry," *Mosaic*, NSF 85-15, Vol. 17, No. 2, Summer 1986b.

National Science Foundation, *Women and Minorities in Science and Engineering*, NSF 88-301 (Washington, DC: National Science Foundation, January 1988c).

National Science Foundation, *Young and Senior Science and Engineering Faculty and Nonfaculty Research Doctorates. 1986* (Washington, DC: National Science Foundation, 1988b).

Personick, V.A., "Industry output and employment through the end of the century," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

Shingleton, J.D. and L.P. Scheetz, *Recruiting Trends 1986-87* (Michigan State University, December 1986).

Silvestri, G.T. and J.M. Lukasiewicz, "A look at occupational employment trends to the year 2000," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

U.S. Congress, Office of Technology Assessment, *Demographic Trends and the Scientific and Engineering Work Force, A Technical Memorandum* (Washington, DC: December 1985).

U.S. Department of Labor, Bureau of Labor Statistics, *Supplement to Employment and Earnings* (Washington, DC: U.S. Department of Labor, July 1987).

Vetter, B. "Women's Progress," *Mosaic*, NSF 86-88, Vol. 18, No. 1, Spring 1987.

Way, P.O. and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, November 1986).

Zampelli, E.M., "Growth, Structural Change, and the Employment of Scientists and Engineers, 1972-1982," (Washington, DC. Catholic University of America, July 1986).

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# Chapter 4
# Resources for R&D and Basic Research

# Resources for R&D and Basic Research

## HIGHLIGHTS

- *Strong recent growth in U.S. research and development (R&D) spending has kept it ahead of that of other Western industrialized nations.* The U.S. spends more on R&D than the next four largest Western industrialized countries combined and devotes the highest percentage of its gross national product (GNP) to R&D (2.8 percent in 1987, the highest rate since 1968). Federal spending on defense R&D is the biggest component of recent growth. (See p. 77.)
- *If only nondefense R&D spending is considered, West Germany and Japan have outpaced U.S. R&D spending for 15 years*, and their rates of investment in civilian R&D as a percentage of GNP have been rising faste.· than the U.S. rate for the past 5 years. (See p. 77.)
- *Over the past decade, U.S. expenditures for both total R&D and basic research have grown faster than GNP.* Total R&D grew by 5.9 percent between 1985 and 1986, basic research by 5.4 percent in constant dollars. (See pp. 2, 77, 241.)
- *Federal agencies provided 63 percent of the total support for academic R&D in 1987*, down from 68 percent in 1980. Industry support for academic R&D grew from 4 percent in 1980 to 6 percent in 1987. (See p. 78.)
- *The Nation is currently experiencing an upsurge of capital spending for academic science and engineering (S/E)*, although the long-term trend in constant dollars is down. In 1985, Federal sources provided 11 percent of the total support for academic capital facilities for science and engineering—their lowest percentage for more than 2 decades. State Governments provided 40 percent of the support for new construction of capital facilities in 1985-86, and funds from tax-exempt bonds contributed another 30 percent. (See p. 80.)
- *Current fund expenditures for research equipment at universities and colleges rose by 17 percent between 1985 and 1986.* From 1980 to 1986, expenditures in this area more than doubled. Funds from all sources grew at approximately the same rate; Federal funds, however, were especially important in computer science. (See p. 82.)
- *The number of supercomputing facilities in the U.S. more than doubled between 1983 and 1985.* University installations increased from 3 to 14 centers, and industry added 30 centers to more than double its supercomputing resources. (See p. 85.)

Previous chapters have described how the people who contribute to science and technology in the United States are recruited and trained. This chapter describes the resources—including funding support—that these persons rely on in their research and development activities.

This discussion particularly focuses on a portion of the overall R&D effort which recently has been receiving special attention: academic R&D and nonacademic basic research. These two complementary activities are increasingly viewed as critical to national R&D strategy, because together they form a crucible for exchanging new ideas and information produced through research.

In the academic context, basic and applied research, as well as the small amount of development activity, are tied closely to the growth of disciplinary knowledge. The results of academic R&D generally are published in the open literature, thereby adding to public knowledge. On the other hand, basic research in industry, nonprofit institutions, and government laboratories is more frequently directed to specific, practical goals rather than to disciplinary knowledge growth. Researchers from these institutions also participate in an open exchange of information, however, contributing their own fundamental advances and drawing on those coming from the academic world. The interaction between academic and nonacademic researchers is a crucial process in effectively using new science and engineering knowledge to meet national goals.

While academic R&D and nonacademic basic research are not exactly the same kind of activities, they have enough in common— and are important enough to innovation in the national research system—to discuss them together at length.

The capital stock of science and engineering is another feature of the research system which has received increasing attention as an element of R&D strategy. Data on investment in R&D plant and research instrumentation at universities and colleges are presented herein, along with survey results on their condition. The size and costs of some special research resources, including supercomputers and data archives, are then reviewed.

Interaction between academic and nonacademic researchers is covered in chapter 5, "Academic R&D and Basic Research: Patterns of Performance"; industrial R&D is discussed in chapter 6, "Industrial Research and Technological Innovation."

## R&D FUNDING

The strong recent growth in U.S. R&D spending, which has kept it well within competitive range of that of other industrialized nations, is largely the result of Federal investment in defense development efforts. These efforts accounted for $19 billion of the $56-billion increase in R&D spending between 1980 and 1986. Industry, on the other hand, has stepped up its funding of basic research and university R&D; however, the vast majority of its funding continues to support in-house development.

### International Comparisons

The U.S. makes by far the largest investments in R&D of any Western country. (See figure O-1 in Overview and appendix table 4-1.) Indeed, the U.S. spends more on R&D than the next four countries combined. Recent growth rates show, moreover, that the U.S. generally is keeping up with its competitors in R&D spending growth. Between 1980 and 1985, R&D spending increased by 36 percent in West Germany, 69 percent in Japan, and 204 percent in France, as compared with 74 percent in the U.S. (See appendix table 4-2.)

*R&D Funding as a Percent of GNP.* The U.S. now invests approximately the same proportion of its GNP in research and development as do the other major noncommunist industrialized countries. In nearly all of these nations, R&D spending has been growing faster than GNP. In recent years, R&D spending in Japan and West Germany has nearly matched R&D spending in the U.S. as a percentage of GNP. (See figure O-2 in Overview and appendix table 4-2.) The recent increase in this proportion has been most dramatic in Japan, where the share went from 2.2 percent in 1980 to 2.8 percent in 1985. this represents a relative increase of 30 percent. In France, the relative increase was 23 percent; in the U.S., 19 percent.

The data in figure O-2 in Overview show that other nations recently have caught up with the U.S. in R&D investments as a percentage of GNP. The nature of these investments must be taken into account, however. If only nondefense R&D is considered, West Germany and Japan have been ahead of the U.S. in R&D spending for 15 years, and their rate of civilian R&D investment as a percentage of GNP has been rising faster than that of the U.S. for the past 5 years. (See figure O-3 in Overview and appendix table 4-3.) In the nondefense area, France has been catching up to U.S. levels, especially in the 1980's, while the United Kingdom has been falling behind

*Funding Sources.* The share of R&D funding in the U.S from business sources is smaller than in Japan or West Germany, but larger than in the U.K. or France. (See figure O-4 in Overview and appendix table 4-1.) In the United States, nongovernment sources provided 51 percent of R&D funds in 1986, of which nearly 48 percent were provided by industry There has been a higher proportion of industrial R&D funding in all countries but France, where government R&D funding has shown very sharp growth in the early 1980's. In Japan, the trend in increased industry spending is most pronounced since 1979. In West Germany, there has been a steady increase in the industrial share since 1975. Finally, in the United States, a strong upward trend in the 1970's in industry R&D funding appears to have slowed in the 1980's.

### Performers

Industry remains the largest performer of R&D in the United States, as well as the fastest growing one. (See appendix table 4-4.) In 1986, industry spent 73 percent of U.S. R&D funds, up from 71 percent in 1980. Nearly two-thirds of the funds spent on industry research and development came from industrial sources, and a little more than one-third from the Federal Government. (See appendix table 4-5; a more detailed discussion of industrial R&D funding appears in chapter 6, "Industrial Research and Technological Innovation.")

In 1986, 12 percent of U.S. R&D funds were spent in Federal laboratories; another 12 percent were spent in universities and colleges and in Federally funded research and development centers (FFRDC's) run by universities. Nonprofit institutions also draw their research and development funding support from more than one source: about 70 percent of the funding, however, are estimated to come from the Federal Government. (Funding sources for academic R&D are discussed later in this chapter.)

### Character of Work

In the 1980's, support for development has grown at a faster rate than has support for either basic or applied research. (See figure O 5 in Overview and appendix table 4-6.) This trend is confined, however, to Federal defense R&D spending. (See figure O-6 in Overview and appendix table 4-37.) Federal defense funds for development—totaling $37 billion in 1987—have more than tripled since 1980, while Federal nondefense development spending—$5 billion in 1987—shrank by 18 percent.

For the same period in industry, growth in development spending lagged behind growth in support for basic and applied research.[1] Basic research made up 5 percent of industry R&D funds in 1986, while applied research was 23 percent. Despite its rapid growth rate throughout the 1980's, industry support for university R&D remains a tiny share (1 percent) of total industry R&D spending. (See following discussion on funding for academic R&D.)

Basic research, applied research, and development are performed to varying degrees in all the Nation's research institutions. (See figure O-23 in Overview and appendix table 4-7.) Industry dominates development activities: in 1985, industrial firms spent $59 billion of the $71 billion spent on development. Outside of industry, Federal Government laboratories accounted for nearly $8 billion in development expenditures in 1985, FFRDC's spent just over $3 billion. In applied research, industry is again the largest performer, accounting for $15 billion (65 percent) of the $23 billion spent on applied research in 1985. Both

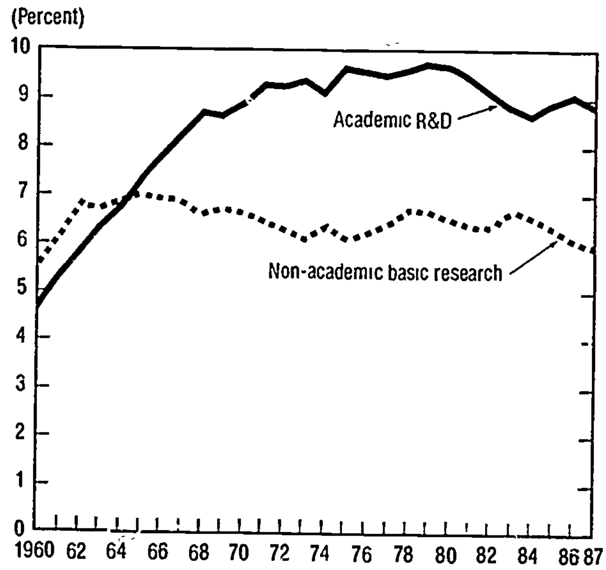
[1]National Science Foundation (1986b)

Federal Government laboratories and universities and colleges also participate to a significant degree in applied research, spending $3.1 billion (13 percent) and $2.6 billion (11 percent), respectively. The largest share of basic research is done by universities and colleges (48 percent in 1985); industry is the second largest performer in this, at 20 percent in 1985.

## FUNDING FOR BASIC RESEARCH AND ACADEMIC R&D

Between 1975 and 1987, academic R&D expenditures remained stable at about 9 percent of R&D spending. Nonacademic basic research spending also stayed flat at about 6.5 percent. (See figure 4-1.) Similarly, applied research spending outside universities and colleges was also relatively stable, at slightly less than 20 percent of R&D. (See appendix table 4-9.)

Figure 4-1.
**Academic R&D and nonacademic basic research as a percent of total R&D**




See appendix table 4-8. Science & Engineering Indicators — 1987

### Funds for Academic R&D

*Sources of Support.* Universities and colleges remained largely dependent on the Federal Government for R&D support in 1985, although funding from industry and institutional sources has been rising. (See appendix table 4-10.) In 1987, the Federal Government was estimated to have provided 63 percent of total R&D funding for universities and colleges. This was down from 68 percent in 1980, bringing the Federal Government to its lowest share of support since 1960. In contrast, institutional funds reached their highest proportional share since these data were first collected in 1953.[2] Institutional funds covered 17 percent of the costs of separately budgeted research in 1986, as compared with 14 percent in 1980.[3]

Industry support is estimated to have increased in 1987 to 6 percent, this was up from 4 percent in 1980. Industry funding was the fastest growing segment of university research support between 1980 and 1985, expanding by 75 percent in constant dollars. (See appendix table 4-10 and figure O-31 in Overview.) Philanthropic contributions earmarked for research are estimated to have grown 85 percent (in current dollars) during that time.[4]

Among Federal agencies, the National Institutes of Health (NIH) obligated the largest amount for academic R&D—estimated at $2.8 billion in 1987. (See appendix table 4-11.) According to the estimated funding figures for 1987 (see appendix table 4-11), the National Science Foundation (NSF) relinquished its long-held second place in support of academic R&D to the Department of Defense (DoD). In 1987, NSF obligated $1.1 billion for this purpose, and DoD $1.2 billion, thus recreating the relative rank order that existed prior to 1970.

*Forms of Support.* Although the Federal Government's share of academic research support has remained relatively stable over the past 2 decades, the form of this support has not.[5] (See figure 4-2.) For example, in 1966, 42 percent of Federal obligations to universities and colleges for R&D were designated for fellowships, traineeships, training grants, R&D plant, and general support for S/E activities (labeled "infrastructure" in the figure). By 1985, Federal support in these categories had declined to a combined 12 percent. At the same time, funding of research projects grew from 58 percent to 88 percent of the total. Also between 1966 and 1985, the indirect cost share of total Federal obligations for academic R&D increased from about 7 percent to about 28 percent. (See figure 4-2.)

### Proposal Activity

Recent survey data comparing proposal activity in 1986 to that in 1980 reflects the growing significance of sponsored research for academic faculty members.[6] Increases in both proposals submitted and proposals funded outstripped faculty growth. Excluding the social sciences, proposal submissions increased at rates ranging from 110 percent in computer science to 4 percent in geosciences. Although the number of proposals awarded increased in 1986, the proportion funded (excluding pending submissions) was down from 1980 in most fields. Nonetheless, the growth in funded proposals exceeded the increase in

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[2]The category "institutional funds" includes unrecovered indirect costs on externally sponsored research.

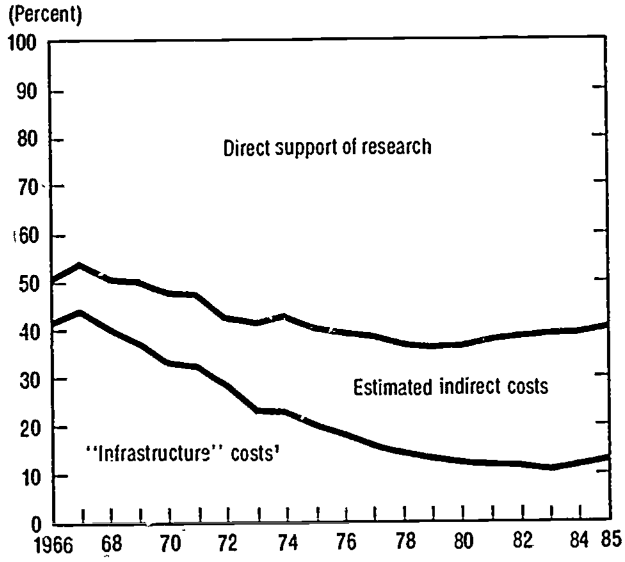
[3]Separately budgeted research is specifically organized to produce research products and is sponsored by an agency either external to the university or separately budgeted by an organizational unit within the institution.

[4]Personal communication from Hayden Smith, Council for Financial Aid to Education.

[5]U.S. General Accounting Office (1986), p. 40.

[6]The survey collected information on full- and part-time faculty from 2,070 departments in 21 fields at 181 doctorate-granting institutions. See National Science Foundation (1987c).

Figure 4-2.
**Percent of Federal research and development obligations to universities and colleges, by major form of funding**




[1]Includes funds for R&D plant; fellowships, traineeships and training grants; general support for science and engineering; and other S/E activities.
See appendix table 4-12. Science & Engineering Indicators — 1987

faculty in most fields; therefore, the average ratios of funded proposals to full-time faculty were up in 1986.

In the three social sciences fields covered by the survey, both proposal submissions and the number of funded proposals were down in 1986. However, submissions dropped more than did funded proposals: success rates thus were higher in social science fields. As in the other fields, the ratios of funded proposals to full-time faculty were up in 1986.

### Funds for Nonacademic Basic Research

The Federal Government was also the main source of support for nonacademic basic research; this included the FFRDC's run by universities, industry, and nonprofit organizations. (See appendix table 4-13.) In 1985, 64 percent of the total funding for nonacademic basic research came from Federal sources, while 33 percent were provided by industry.

*FFRDC's and Federal Intramural Laboratories*. The Department of Energy (DOE) provided the bulk of the basic research obligations to FFRDC's. (See appendix table 4-14.) DOE spent an estimated $744 million on these in 1987—82 percent of total FFRDC support. The National Science Foundation obligated $92 million (10 percent).

Federal intramural basic research is concentrated in a somewhat different set of agencies: NIH (which spent an estimated $700 million in 1987, or 32 percent of the total), National Aeronautics and Space Administration (NASA) (19 percent), the Department of Defense (12 percent), and the Department of Agriculture (14 percent).[7] (See appendix table 4-15.) Basic research funding from all of these agencies for both FFRDC's and government laboratories increased by about 34 percent from 1980 to 1987 in constant 1982 dollars.

*Industrial Basic Research*. Support for basic research in industry largely comes from companies' own funds: in 1987, 80 percent of basic research expenditures were estimated to have come from companies' own financial resources. (See appendix table 4-16.) The non-Federal share has been fairly constant for the past 2 decades. Nearly 60 percent of the 1987 Federal obligations for industrial basic research came from NASA. (See appendix table 4-17.) DoD was the second largest contributor with 23 percent. Two industries—electrical equipment and aircraft and missiles—received most of the Federal funds.[8]

### Funding by Fields of Science and Engineering

Federal basic research obligations provide the best indicator of overall spending by S/E field, since information on non-Federal spending is not available by field for all performing sectors.

In 1987, an estimated 12 percent of Federal basic research funds went to engineering and 88 percent to science. (See appendix table 4-18.) Federal support for engineering has grown somewhat faster than has support for science over the past decade, increasing between 1976 and 1986 by 92 percent in constant 1982 dollars versus 56 percent for the sciences. Between 1985 and 1986, obligations for basic engineering research increased 6 percent in constant dollars, as compared with less than 1 percent for the sciences.

The life sciences received an estimated 47 percent of the science and engineering total in 1987, followed by the physical sciences at 24 percent. (See appendix table 4-18.) Among the sciences, mathematics and computer science grew most quickly; both increased by 94 percent in constant dollars over the past decade. More recently, however, psychology and the social sciences experienced the most rapid growth, increasing in constant dollars by an estimated 10 percent and 13 percent, respectively, between 1986 and 1987.

*Universities and Colleges*. In 1986, 85 percent of academic R&D spending was in science; the remaining 15 percent was spent on engineering. (See appendix table 4-19.) Over the last decade, expenditures for engineering R&D in the academic sector have been growing faster than has spending for R&D in the sciences. Engineering spending increased by 106 percent between 1976 and 1986 in constant dollars, as compared with a growth of 53 percent in the sciences. (See figure O-24 in Overview and appendix table 4-19.)

Slightly more than one-half (54 percent) of academic R&D spending went to the life sciences. Of this amount, 24 percent went to the medical sciences 17 percent to the

[7]These numbers should be taken as approximate, since the obligations figures for intramural research also include agency expenditures for managing extramural research programs

[8]National Science Foundation (198?), table B-3, p 19

biological sciences, and 10 percent to the agricultural sciences. (See appendix table 4-19.) Twelve percent of total academic R&D spending supported the physical sciences; this included 6 percent for physics and 4 percent for chemistry. Another 7 percent went to the environmental sciences.

Some of the smaller sciences have been the fastest growing over the past decade. Spending for R&D in computer science, for instance, increased by 292 percent from 1976 to 1986 in constant dollars. Increases in physics, astronomy, and mathematics funding all exceeded inflation by 70 percent or more. On the other hand, funding for the social sciences grew only 16 percent over the decade—slower than the inflation rate during the same period.

Although 62 percent of academic R&D expenditures came from Federal funds in 1986, the percentages by field ranged from a high of 82 percent in physics to a low of 29 percent in the agricultural sciences. (See appendix table 4-20.) The social sciences have the highest share of non-Federal funding (64 percent), and the physical sciences the lowest (23 percent). About equal proportions of academic science and academic engineering funds come from the Federal Government.

*Industry.* Basic research expenditures in industry are distributed somewhat differently among fields than in university R&D:[9] notably, in industry, engineering and the physical sciences receive more emphasis and the life sciences less. In 1983, engineering research received 32 percent of total industrial basic research funds; this was more than twice the share of engineering in university R&D. (See appendix table 4-21.) Similarly, chemistry received 26 percent of industrial spending (43 percent went to the physical sciences as a whole), as compared with only 4 percent of university spending (12 percent for all physical sciences). On the other hand, the life sciences consumed only 13 percent of industrial basic research spending, versus 54 percent of academic R&D funding.

From 1973 to 1983, basic research spending in industry more than tripled in current dollars—a 59-percent growth in constant dollars. (See appendix table 4-21.) Basic research activities grew at similar rates across most S/E fields, with somewhat more rapid growth occurring in the relatively small areas of the geological and atmospheric sciences. Basic research in engineering and the biological sciences were also expanding rapidly, growing 35 percent and 39 percent, respectively, between 1981 and 1983 in constant dollars.

## PLANT AND EQUIPMENT

The plant and equipment available for use at research-performing institutions are another major R&D resource. Unfortunately, information on this aspect of the research infrastructure is fragmentary: estimates of the national stock of research facilities and instrumentation are available only for universities, and the data on R&D plant spending are more complete for universities than for other sectors. Given this lack of comprehensive data, this section reports exclusively on universities' aggregate research capital stock.[10]

There are several discernible trends in R&D capital stock. First, capital investment in science and engineering is cyclical. Although the long-term trend in constant dollars has been downward over the last 2 decades, the Nation is currently in an upsurge of capital spending for academic science and engineering, with engineering receiving the largest percentage increases. In response to widespread concern over research instrumentation, equipment expenditures have been expanding rapidly in the 1980's. Further, special Federal instrumentation programs are helping to ensure that new instrumentation is accessible to more than the major research universities. Finally, instrument intensity varies among the sciences, but is not necessarily connected to the trend toward shared-access research facilities or to collaboration rates.

### Facilities Spending[11]

Since the 1960's, Federally funded capital S/E expenditures at universities and colleges have been declining in constant dollars, and fluctuating in current-dollar terms. (See figure O-25 in Overview and appendix table 4-22.) For example, in 1966, Federal support for academic science and engineering facilities reached its highest proportional share (32 percent); in 1985, it was at its lowest point ever (11 percent). Since 1979, however, the Nation's total capital spending in universities and colleges has been on the upswing. In 1986, expenditures on facilities for research and instruction in science and engineering were 99 percent higher in current dollars than they had been in 1980, and 20 percent higher than they had been 1 year earlier. (See appendix table 4-22.)

The largest share of funds (80 percent) from the current increase in capital spending is going to science rather than engineering. (See appendix table 4-23.) However, spending on engineering facilities expanded rapidly from 1984 to 1986 for a total increase of 121 percent in current dollars.

Among the sciences in 1986, capital spending in the life sciences received the largest share: two-thirds of all funds for science facilities, or 53 percent of the S/E total. (See appendix table 4-23.) Capital spending in the life sciences was growing slowly; it was only 19 percent higher in 1986 than in 1976. In contrast, capital spending in the physical sciences was 107 percent higher at the end of that period. In the mathematical and computer sciences, 1986 spending was more than 2.5 times the 1976 figure. Spending on

[9]Data on basic research by field are not available for universities.

[10]There is no continuous collection of data on industry R&D plant, but attempts have been made to describe new investments systematically. See (for example) Conference Board (1987). For figures on Federal obligations for R&D plant, see National Science Foundation (1985c), (1986a), and (1987b).

[11]The term *facilities* is used here to stand for capital investment expenditures for S/E research or instruction at those universities and colleges spending $50,000 or more annually on separately budgeted R&D. The constant-dollar calculations are based on the GNP price deflator. The figures include some money for major equipment purchased from capital, rather than from current operating funds, but there is no way of knowing how much. For more information on definitions, see National Science Foundation (1985b).

psychology facilities in the same period had nearly tripled, but spending for the other social sciences was only up 15 percent. In the environmental sciences, the level of investment was actually 4 percent lower in 1986 than in 1976 (current dollars).

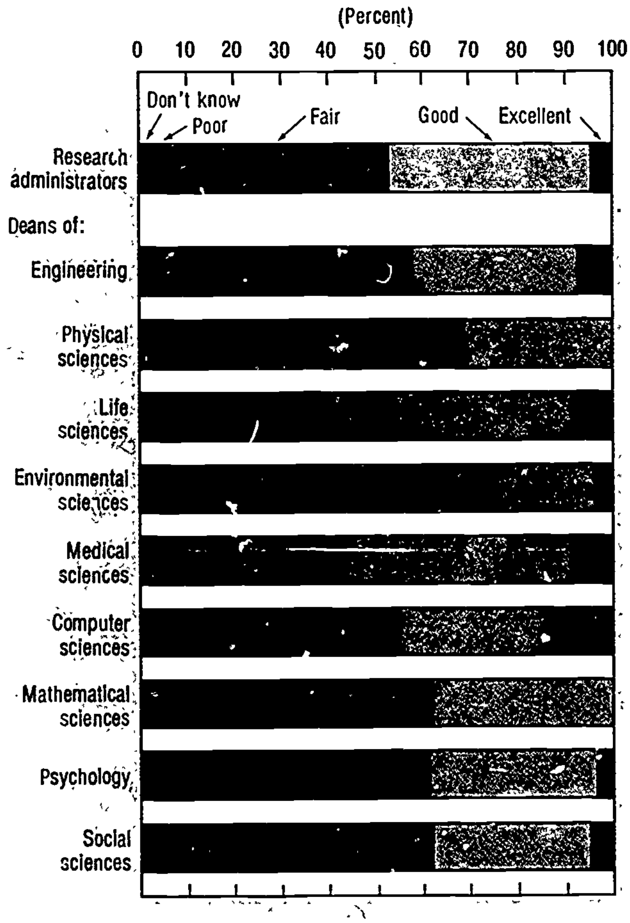
*Condition of Facilities.* As shown in figure O-25 in Overview, real-dollar investments in academic science and engineering facilities have declined during the last 18 years. However, the level of need for research facilities depends on more than just capital expenditures. On the one hand, if adequate facilities are established, they may be sufficient for decades. On the other hand, existing facilities can become inadequate through lack of maintenance.[12] They can become crowded if the number of researchers grows, and can become obsolescent through changes in the character and technology of research.

Indicators of the status and condition of facilities in selected S/E fields are available from a 1986 survey among doctorate-granting research universities.[13] The survey showed that although the average institution devotes 513,000 square feet on campus to research, the figures for individual campuses ranged as high as 3.3 million square feet. The average for the top (in terms of R&D expenditures) 50 schools was 1.032 million square feet. More than one-half of the universities surveyed were in the process of building new research facilities that would result in a net average increase of 73,000 square feet per campus. The top 50 schools had an average of 98,000 square feet under construction; the other schools averaged 58,000.

The overall condition of university research facilities was appraised in the survey by deans and research administrators in the relevant S/E fields. (See figure 4-3.) Facilities in the medical sciences[14] were judged to be in the best condition: 56 percent were rated excellent or good by the deans. Facilities for the environmental sciences—where investment has tailed off—were found least satisfactory. Seventy-three percent of the deans rated facilities in that field fair or poor, and only 24 percent judged them to be in good or excellent condition. Only 31 percent of the deans considered their schools' physical sciences facilities to be in good or excellent condition, despite the rapid increase during the past decade in spending in that area (noted in appendix table 4-23).

Administrators and deans surveyed felt that lack of space was a more pressing problem on their campuses than was the quality of the existing space. About one-third of the respondents considered facilities to be the most pressing problem on their campuses in the next 5 years. About one-half judged the facilities on their campuses to be in good or excellent condition; about one-half judged them to be in fair or poor condition.

Figure 4-3.
**Academic officials' views regarding condition of research facilities: 1986**




See appendix table 4-24.

Science & Engineering Indicators — 1987

Survey respondents reported that their facilities in virtually every field were crowded. (See figure 4-4.) Engineering was identified as having the most serious space problem, closely followed by the social sciences. The mathematical sciences were least crowded, although only one-third of the deans felt that those facilities provided adequate space.

*Facilities Plans.* Three-quarters of the schools surveyed in 1986 expected to construct new research facilities within the next 5 years. In addition, 77 percent of the schools surveyed reported that they were upgrading or renovating facilities, and 74 percent were undertaking major repairs in academic year 1985/6. Engineering was the area of greatest facilities construction activity: two-thirds of the institutions with engineering programs were building or planning to build new engineering facilities within the next 5 years.

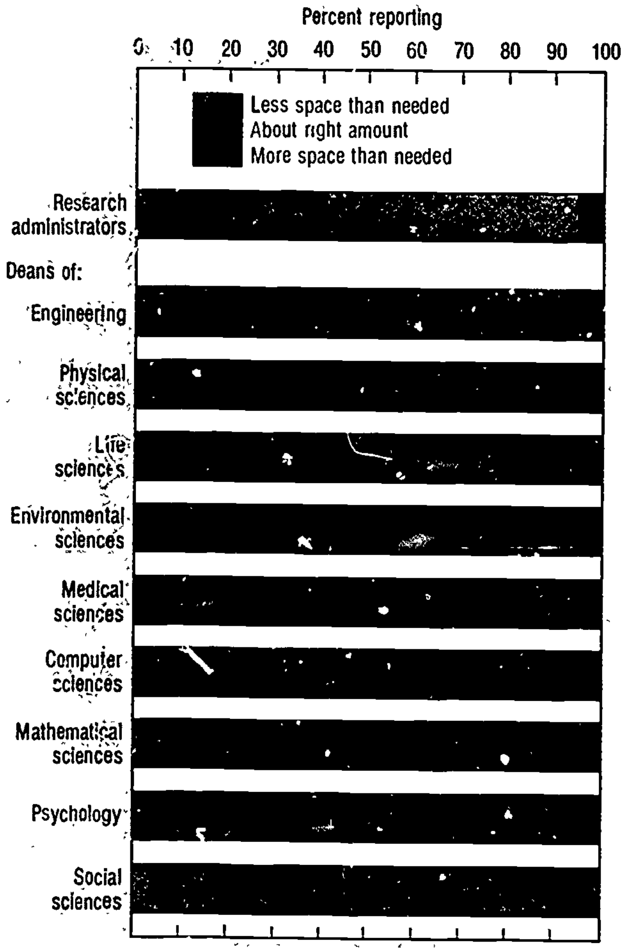
According to survey respondents, State Governments—at 40 percent of total funding—provided the

[12]Maintenance expenditures are not included in the data in figure O-25 in Overview.

[13]This survey inquired about research facilities only; it did not include information on equipment or instructional facilities. The survey thus has a narrower scope than does the data on spending reported in the last section. In addition, the sample of universities was different than the set used to gather the capital expenditures data. For more detailed information, see National Science Foundation (1986c).

[14]"Medical sciences" is a subcategory of life sciences used for this particular study.

Figure 4-4.
**Academic officials' views regarding sufficiency of research space: 1986**




See appendix table 4-25. Science & Engineering Indicators — 1987

highest proportion of new construction funds. Tax-exempt bonds funded 30 percent of new construction costs, 14 percent was derived from private donations or endowments, a d Federal funds covered 10 percent. Private institutions were more dependent than public ones on Federal funding. The administrators anticipated that 10 percent of the new construction costs (1986-91) of private schools would be financed with Federal funds as compared with 4 percent of new construction at public institutions.[15]

## Equipment Spending[16]

Equipment expenditures from current (rather than capital) funds have also increased dramatically in recent years. (See figure O-25 in Overview.) In 1986, U.S. universities and colleges spent $765 million from their current fund accounts on research equipment. These expenditures more than doubled since 1980 (58-percent increase in constant dollars), the first year for which data are available; facilities investments, in contrast, increased only 99 percent during the same time period. Sixty-five percent ($497 million) of the funds spent on equipment came from the Federal Government. While this percentage closely matches that for overall Federal support of university R&D (i.e., 64 percent), it far exceeds the Federal share of facilities expenditures (11 percent). Federal support for instrumentation increased at a slightly slower pace than did non-Federal support: a 106-percent increase from 1980 to 1986 as compared with 119 percent in non-Federal support. (See appendix table 4-26.)

Between 1980 and 1986, spending for equipment in the life sciences grew more slowly than spending in all fields combined (68 percent as compared with 111 percent). Equipment expenditures in the physical sciences, on the other hand, increased at nearly twice the average rate (205 percent between 1980 and 1986). Expenditures in engineering more than doubled over this time period, increasing by 145 percent.

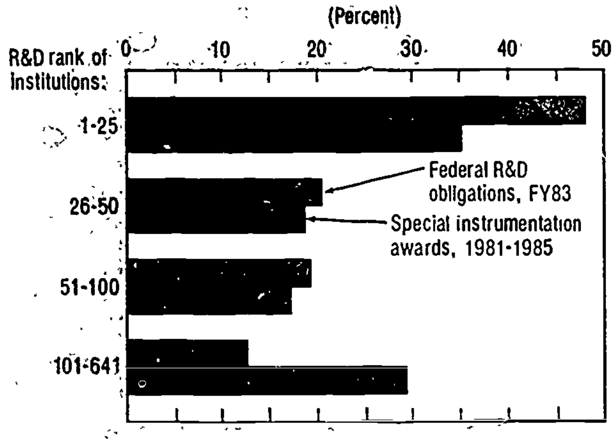
*Special Programs.* The growth in Federal funds for research equipment is due in part to instrumentation programs implemented in several agencies during the early 1980's. The National Science Foundation, Department of Defense, Department of Energy, and National Institutes of Health all had initiatives in this area. The amounts awarded by these programs represented only about 26 percent of overall Federal support for instrumentation by 1985, but—as shown in appendix table 4-27— the programs were growing very quickly.

These special programs helped distribute Federal instrumentation to a wide set of universities. A comparison of total Federal R&D funds to groups of universities and those funds distributed through special instrumentation programs is presented in figure 4-5. Excluding the top 100 in Federal R&D support, the remaining universities received 12 percent of overall Federal R&D funds, however, these same universities received nearly 30 percent of the funds awarded under special instrumentation programs. When all Federal instrumentation awards (both overall and special program) are considered, funding for non-top-100 universities more closely matches their share of total R&D funding. These data suggest that the special programs have performed a complementary distributive function that the research project grant system alone has not performed.

[15]See National Academy of Sciences (1986), pp 32-38, for a discussion of alternative sources of finance for facilities funding

[16]Data here refer to expenditures from current (operating) funds for research equipment, in contrast to the capital funds reported earlier in this chapter. Most universities keep separate current and capital funds, and apply current funds for ongoing activities. Note also that the data used here are limited to funds for research equipment, and do not include funds for instructional equipment. The term *instrumentation* is used throughout this chapter to refer to research equipment.

Figure 4-5.
**Comparison of awards to colleges and universities under special Federal instrumentation programs with total Federal R&D obligations, by R&D rank of institutions**




See appendix table 4-28. Science & Engineering Indicators — 1987

The instruments awarded under the four agency programs match reasonably well those types of instruments that universities say they need. A 1982-83 survey asked departmental chairpersons and facilities administrators to name the three instruments their departments most needed to purchase.[17] The match between the instruments awarded under the four agency instrumentation programs and the needs expressed by the administrators is shown in figure 4-6. Computers and spectrometers were the instruments named most frequently, and they also were awarded most frequently by Federal programs. Computers, however, made up a smaller share of awards than of needs expressed by the administrators; the figures were closer for spectrometers.

*Instrument Inventory.* In 1982/83, more than 46,000 large instrument systems (with an original cost ranging from $10,000 to $1 million) were located on university campuses, according to an estimate based on the survey sample.[18] The estimated aggregate purchase price of the equipment was $1.6 billion.[19] Between 1982 and 1985, there was substantial turnover in research equipment in the physical sciences, engineering, and computer science. (The other fields have not yet been resurveyed.) In the physical sciences and engineering, roughly one-fourth of the instrument systems that were in active use in 1982 were no longer being used in 1985. Conversely, almost one-half of the systems being used for research in 1985 had been acquired in the 1983-85 period. In computer science, turnover rates were even higher: more than 40 percent of the equipment in research use in 1982 had been retired by the end of 1985, and three-fourths of the systems in research use in 1985 had been acquired since the 1982 study.[20]

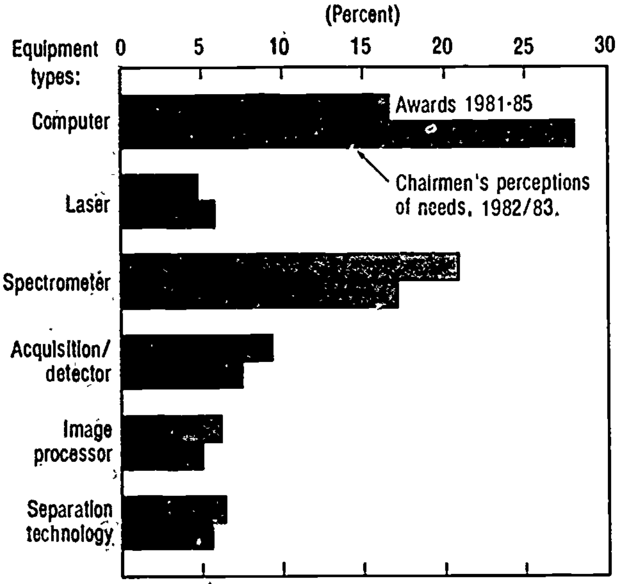
Of the systems in use at the time of the 1982/83 survey, 22 percent were judged by their users to be "state-of-the-art," one-half were considered in excellent condition, and 10 percent in poor condition. Fifty-three percent of the systems were 1 to 5 years old, another 24 percent were 6 to 10 years old. Of those systems purchased within the last 5 years, 68 percent were thought to be in excellent condition, a rating applied to only 27 percent of those more than 10 years old. (See figure 4-7.)

A number of indicators suggest that, between 1982 and 1985, the general quality of academic research instrumentation has improved in the three fields that have been resurveyed. For example, the proportion of all existing research equipment that is completely inactive (and presumably obsolete, either mechanically or technologically) declined by 3 to 10 percent in all three fields. Also, the number of instrument systems judged by the responsible principal investigators as state-of-the-art increased by 48 percent in engineering, 73 percent in the physical sciences, and 167 percent in computer science. Furthermore, the extent of reliance on non-state-of-the-art equipment declined in all three fields: the proportion

[17] National Science Foundation (1985a).
[18] Ibid.
[19] Not all of the equipment on campus at the time of the survey was in use: 2 percent had not yet come on line, and 20 percent had been retired Only those systems in use are discussed here.

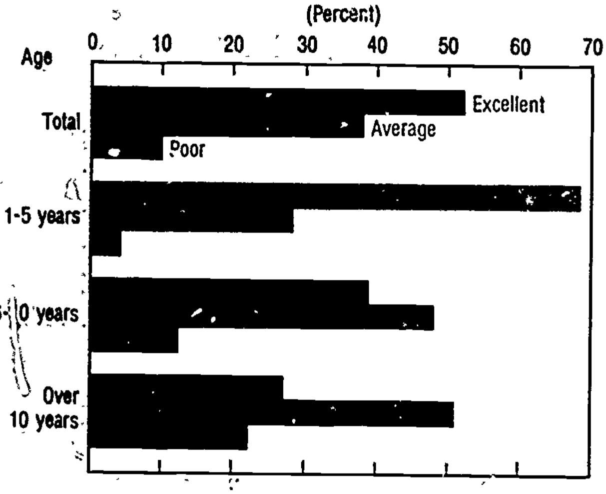
[20] National Science Foundation (1987a).

Figure 4-6.
**Comparison of perceived instrumentation needs with awards under special Federal instrumentation programs, by type of equipment**




See appendix table 4-29. Science & Engineering Indicators — 1987

Figure 4-7.
**Condition of academic research instrument systems by age of system**




See appendix table 4-30. Science & Engineering Indicators — 1987

of non-state-of-the-art instrument systems that were the most advanced instruments to which their users had access declined by 7 percent in engineering, 9 percent in the physical sciences, and 19 percent in computer science.[21]

Research equipment expenditures at universities and colleges are approximately proportional to equipment inventory share by S/E field. The 1983 baseline survey showed that the largest stock of equipment was devoted to the life sciences (38 percent), followed by the physical sciences (25 percent), and engineering (20 percent).[22] (See appendix table 4-31.) In 1986, the life sciences spent 42 percent of current fund expenditures for research equipment, the physical sciences received 21 percent, and engineering used 18 percent. (See appendix table 4-26.)

*Maintenance and Repair.* Total maintenance and repair costs for research instruments are roughly proportionate with instrument spending. (See appendix table 4-32.) According to the 1983 survey, the average is 16 percent of total equipment expenditures, with variations ranging from 12 percent in the agricultural sciences to 21 percent in computer science. Approximately 40 percent of maintenance expenditures were for service contracts and field service, 40 percent were for university-employed service personnel, and 20 percent were for service supplies, equipment, and facilities. Forty-one percent of the instrument systems in the survey were located in shared-access facilities, as were 38 percent of state-of-the-art systems.[23]

*Instrument Intensity.* As noted above, there was a high rate of increase in equipment spending for the physical sciences, this increase is reflected in a correspondingly high level of instrumentation spending per physical scientist. (See appendix table 4-33.) The 1983 equipment inventory showed an average of $24,800 worth of equipment per scientist in the physical sciences, in chemistry, the figure was $27,100. The environmental sciences are also very equipment-intensive by this measure, with $18,000 worth of equipment per academic scientist.

Another form of equipment intensity is the use of shared-access facilities. (See appendix table 4-34.) In 1983, 41 percent of instrument systems were located in such facilities. Materials science and computer science showed the highest percentages of instruments in shared facilities (81 percent in each case). Engineering instruments and those used in the environmental sciences were also relatively likely to be shared (50 and 48 percent respectively), as were instruments for interdisciplinary research (73 percent). The most equipment-intensive fields, however—as measured by the value of the equipment inventory per scientist—are *not* those in which instruments are housed in shared facilities. The physical sciences, for instance, show a low percentage of instruments in shared-access facilities (35 percent).

Newer systems are generally less likely than older ones to be located in shared-access facilities. (See appendix table 4-35.) Thirty-eight percent of the systems that were less than 5 years old at the time of the inventory were shared, as compared with 48 percent of those more than 10 years old. Only in the agricultural and environmental sciences was this trend reversed, with newer systems more likely to be shared than older ones.

*Cross-Institution Collaboration.* Shared instrumentation is often seen as a major factor in the increase of S/E collaboration among researchers working in different institutions. The figures on institutional collaboration suggest, however, that instrumentation is not the only factor involved. In fact, collaboration rates have increased in equipment-intensive fields, but they have gone up in other fields as well. (See appendix table 4-36.) This type of collaboration has grown from 24 percent of all published articles in 1973 to 36 percent in 1984. The fields with the highest levels of institutional collaboration are *not* those that are most equipment-intensive or those in which equipment is most often located in shared-access facilities. Clinical medicine has the highest collaboration rate: more than one-half of all articles in that field were coauthored across institutions in 1984. It is followed by the earth and space sciences and the rest of biomedicine. Chemistry, the most equipment-intensive field, is one of the least collaborative (24 percent of 1984 articles), as is mathematics (also at 24 percent). Of course, patterns of institutional collaboration within fields may be related to instrument use even if comparisons across fields do not show the connection.

## SPECIAL RESEARCH RESOURCES

Many research areas require special resources beyond buildings, equipment, and the expenses of ongoing re-

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[21] Ibid.

[22] These percentages are calculated using the purchase price of the equipment systems. The data are limited to systems that cost between $10,000 and $1 million, and are estimated based on a sample of universities. See National Science Foundation (1985a).

[23] The pattern of shared access facilities by field is discussed in the following section.

search. Computing facilities are an example. Archives of data and research materials are important in many disciplines, as are highly specialized research facilities. This section discusses some instances of such resources.

### Supercomputers

Supercomputers provide enhanced problem-solving capabilities to researchers in many disciplines. Supercomputing capacity is increasing rapidly among U.S. research-performing institutions. The number of supercomputer facilities in the U.S. more than doubled between 1983 and 1986 (see table 4-1); university supercomputing resources increased in this period from 3 to 14 centers.[24] The largest number of supercomputing installations (34) was added in government laboratories; 30 new installations appeared in industry. Comparable numbers for supercomputer installations in Japan show even faster growth.

### Collections of Research Materials

Among the capital resources of many fields are archives of research materials. The collections themselves can be vast, even though the costs of managing and maintaining them are modest. For instance, nearly 4,000 collections of biological materials that serve as the basis for systematic and evolutionary biology have been identified in the United States.[25] About two-thirds of these, it is estimated, are maintained in academic departments. Another 29 percent are housed in freestanding institutions or academic museums. Because many of the collections are small and have no special funds allocated for management, the average budget for the collections is low: $5,620 in 1981. Budgets ranged as high, however, as $1.5 million that year. The estimated total cost of collection management for 1981 was nearly $15 million.

Other areas of biology depend on libraries and stocks of living organisms. For instance, a gene library project is under way at Lawrence Livermore and Los Alamos National Laboratories.[26] The project purifies and packages chromosomes for use by researchers studying and diagnosing genetic disease, linkage, and pedigree analysis, as well as those studying gene structure and regulation. A multi-million dollar project to map the human genome is also under consideration.[27] In the agricultural sciences, a network of institutions makes germplasm available for research purposes. More than 400,000 samples have been acquired by the National Plant Germplasm System, and another 7,000 to 15,000 domestic and foreign additions are made annually.[28] Sixteen such data collections were supported by NSF in 1986 for a total of $1.6 million; the Department of Agriculture and NIH sponsor other collections.[29]

Earth and environmental scientists depend on publicly maintained archives of data resources in their work. In the earth sciences facilities exist for storing ocean-bottom sedimentary cores, ice cores, and meteorites. In 1983-84, one collection alone distributed 6,179 samples of ocean-bottom cores.[30] Archives of computerized data from weather satellites also are growing at a rapid rate. The National Environmental Satellite, Data, and Information Service—which manages earth-observing satellite systems and global data bases in meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences—has been adding 30 million meteorological observations annually to its collection.[31]

[24] Five of these centers were supported by the National Science Foundation, at the University of Illinois, the Von Neumann Center in Princeton, Cornell University, the University of California at San Diego, and the Pittsburgh Supercomputer Center.

[25] Edwards, Davis and Nevling, eds. (1985).

[26] These libraries are available from a repository through funding by the NIH Division of Research Resources.

[27] See the Spring 1987 issue of *Issues in Science and Technology* for a discussion of this project.

[28] Source: Agricultural Research Service.

[29] Information provided by the National Science Foundation, Division of Biotic Systems and Resources.

[30] Cassidy (1984), pp. 243-245.

[31] Information provided by the National Oceanic and Atmospheric Administration.

**Table 4-1. Supercomputer installations in the United States and Japan: 1983-86**

| Type of installation | 1983 United States | 1983 Japan | 1984 United States | 1984 Japan | 1985 United States | 1985 Japan | 1986 United States[2] | 1986 Japan |
|---|---|---|---|---|---|---|---|---|
| Government research laboratories[1] | 23 | 2 | 26 | 4 | 39 | 9 | 57 | 19 |
| Universities[1] | 3 | | 5 | | 14 | | 14 | |
| Industry | 20 | 3 | 22 | 9 | 46 | 17 | 50 | 33 |

[1] The categories "government research laboratories" and "universities" cannot be separated in the Japanese environment.
[2] Estimated.

SOURCE: United States: National Science Foundation, Office of Advanced Scientific Computing; Japan: Tokyo Office of the U.S. National Science Foundation, Report Memorandum #128, July 23, 1987

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In the social sciences, several national survey data bases both serve as archives for historical patterns and provide information on current trends. The Panel Study of Income Dynamics, for instance, is the only survey of income, occupation, education, family composition, and other social and economic family characteristics which has repeatedly interviewed the same nationally representative sample of respondents over a significant period of time. The data are invaluable in analyzing income and labor supply dynamics. Similarly, the National Election Studies and General Social Survey track political and social trends. As in the earth sciences, archives of social science data are of continuing importance. NSF's Division of Social and Economic Sciences now requires data produced under some Federal grants to be made publicly available. The International Association for Social Sciences Information Services and Technology provides information on archives around the world.[12]

[12]Information provided by the National Science Foundation, Division of Social and Economic Sciences.

## REFERENCES


Cassidy, D.S., "Antarctic Marine Geology Research Facility and Core Library, 1983-1984," *Antarctic Journal of the United States*, Vol. 19, No. 5, 1984.

Conference Board, "Locating R&D Facilities," Report #892 (January 1987).

Edwards, S.R., G.M. Davis, and L.I. Nevling, eds., *The Systematics Community* (Lawrence, KS: Association of Systematics Collections, July 1985).

*Issues in Science and Technology*, Vol. III, No. 3, Spring 1987.

National Academy of Sciences, *Academic Research Facilities: Financing Strategies*, report of a conference July 22-23. 1985 (Washington, DC: National Academy Press, 1986).

National Science Foundation, "Academic Research Equipment in the Physical and Computer Sciences and Engineering: 1982 and 1985" (Washington, DC: National Science Foundation, September 1987a).

National Science Foundation, "Academic Research Equipment in Selected Science/Engineering Fields, 1982-83" (Washington, DC: National Science Foundation, August 1985a).

National Science Foundation, *Academic Science and Engineering, R&D Funds* (Washington, DC: National Science Foundation, 1985b).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1985* (Washington, DC: National Science Foundation, 1985c).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1986* (Washington, DC: National Science Foundation, 1986a).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1987* (Washington, DC: National Science Foundation, 1987b).

National Science Foundation, *National Patterns of Science and Technology Resources* (Washington, DC: National Science Foundation, 1986b).

National Science Foundation, *Science and Engineering Faculty at Research-Intensive Institutions. 1986* (Washington, DC: National Science Foundation, 1987c).

National Science Foundation, "Science and Engineering Research Facilities at Doctorate-Granting Institutions" (Washington, DC: National Science Foundation, September 1986c).

National Science Foundation, *Trends to 1982 in Industrial Support of Basic Research*, NSF 83-302 (Washington, DC: National Science Foundation, 1983).

U.S. General Accounting Office, *University Funding: Federal Funding Mechanisms in Support of University Research*, GAO/RCED-86-53 (Washington, DC: General Accounting Office, February 1986).

# Chapter 5
# Academic R&D and Basic Research: Patterns of Performance

# Academic R&D and Basic Research: Patterns of Performance

## HIGHLIGHTS

- *In 1985, almost one-half (49 percent) of the doctoral-level scientists and engineers in academic research and development (R&D) or basic research were supported by Federal funds.* This proportion has dropped in recent years, down from 56 percent in 1977 In industry, the percentage dropped from 21 to 14 percent, and in universities and colleges from 55 to 48 percent. (See pp. 90-91.)
- *The number of doctoral-level women scientists and engineers engaged in academic R&D or nonacademic basic research nearly doubled between 1975 and 1985.* In the same period, the percentage of women in these activities increased from 9 percent to 15 percent. (See p. 91.)
- *The number of doctoral-level blacks, Asians, and other minority groups also nearly doubled between 1975 and 1985,* and the percentage of blacks increased from 0.78 to 1.16 during this period. However, since black enrollment in science and engineering (S/E) degree programs has slowed in recent years, future gains are not likely to be as dramatic. Moreover, black participation in research is still low when compared with the percentage of blacks in the total population of scientists and engineers. (See p. 91.)
- *The number of scientists and engineers engaged in academic R&D or nonacademic basic research doubled between 1976 and 1985.* The fastest increase was among computer specialists, whose numbers went from 1,200 in 1976 to 6,000 in 1984. The number of engineers in research increased by 133 percent between 1976 and 1985. The number of scientists grew 97 percent. (See pp. 93-94.)
- *The percentage of doctoral-level researchers who moved from universities and colleges to industry was somewhat higher between 1983 and 1985 than it had been a decade earlier.* This trend was more notable among scientists than among engineers. Similarly, the percentage of researchers moving from industry to academia also was higher in 1983-85 than a decade earlier. In all cases, however, the proportions were small, around 2 percent. (See pp. 94-95.)
- *Research collaborations across sectors in the United States are on the rise.* In 1973, only 19 percent of articles with authors working in industry were coauthored with someone working in another sector. By 1984, 36 percent were coauthored across sectors, 24 percent with university researchers. Cross-sector collaboration rates were also up for nonprofit institutions, Federally funded R&D centers (FFRDC's), and Federal Government laboratories. (See pp. 95-96.)
- *Universities and colleges are patenting more frequently.* The rate of increase in patents granted between 1980 and 1985 was more than double that for the preceding 5 years. The most active patent classes are bio-affecting drugs, molecular biology and microbiology, and surgical inventions. (See p. 97.)
- *Foreign citizens received a larger share of the science and engineering doctorates granted by U.S. universities in 1986 than at any time in the preceding decade,* and more of these citizens planned to stay and work in the United States. Twenty percent of the S/E doctorates awarded in the U.S. in 1984 went to foreign nationals, as compared with 12 percent in 1960. In 1983, 47 percent of these foreign doctoral recipients had firm plans to stay in the U.S., compared with 29 percent in 1972. In contrast, the number of U.S. nationals who planned postdoctoral study abroad has fluctuated around 1.5 percent of the total for several decades. (See p. 98.)
- *Cross-national research contacts are on the rise, as indicated by increases in exchange visas and international coauthorships.* More than 97,000 academic exchange visas were issued in 1984 to allow overseas visitors to attend U.S. universities and colleges; this represented a 7-percent increase from 1983. Similarly, internationally coauthored articles rose from 13 percent in 1973 to 17 percent in 1982. More than 25 percent of publications from FFRDC's in 1984 were internationally coauthored, as compared with 18 percent for private firms and 16 percent for universities. (See pp. 98-99.)
- *The U.S. still produces about 35 percent of the world's science and engineering literature,* and receives more citations than any other country. In relation to the number of articles produced, however, there has been a slight decrease in world attention to the U.S. literature. The 1982 U.S. literature received only 83 percent as many citations from the rest of the world between 1982 and 1984 as would be expected based on the number of U.S. articles published. (See p. 99.)

The preceding chapter described those resources available in the United States for research in science and engineering, particularly focusing on resources for academic R&D and nonacademic basic research—two activities that are increasingly treated as critical in national R&D strategy. This chapter focuses on how the people in science and engineering use those resources to produce new knowledge.

The chapter first presents a statistical description of the set of institutions—including universities and colleges, other nonprofit institutions, government laboratories, and industrial firms—that are involved in basic research in some form. Data on U.S. scientists and engineers who are engaged in academic R&D or basic research are presented, and their distribution among fields of science and research-performing sectors is described. Movement of scientists and engineers out of research and into other activities—such as R&D management, development, and teaching—is also discussed.

This chapter also discusses cross-sectoral contacts among researchers, including cross-sectoral mobility, coauthorship, and a variety of university-industry interactions. These contacts are often considered essential if new science and engineering knowledge is to be both useful and used. Finally, data on international contacts, another important consideration in national R&D strategy, are presented.

## INSTITUTIONS

Although basic research often is associated with academic settings, nonacademic institutions—i.e., government laboratories, nonprofit institutions, and industrial firms—are also important contributors. Altogether, nearly 1,600 institutions, academic and nonacademic, are involved in the performance of basic research in the United States.[1] Their expenditures vary substantially. Among universities, the top 100 (which account for 18 percent of all academic R&D performers) spend 83 percent of R&D funds. (See table 5-1.) FFRDC's are generally very large organizations, with annual budgets ranging as high as $688 million in 1985.[2]

Among industrial firms, the 56 largest R&D-performing companies spent 44 percent ($1.1 billion) of industry's in-house basic research funds in 1984. (See table 5-2.) Company funds for in-house basic research are heavily concentrated in a few industries. chemicals and allied products, petroleum refining, machinery, electrical equipment, motor vehicles, and scientific instruments. Together these industries account for 78 percent of industry's total basic research expenditures.[3]

**Table 5-1. Distribution of R&D funds among academic performers, by R&D rank: 1986**

| R&D rank | Funds (Millions of dollars) | Percent |
|---|---|---|
| All institutions | 10,718 | 100 |
| Top 10 | 2,284 | 21 |
| Top 20 | 3,779 | 35 |
| Top 50 | 6,516 | 61 |
| Top 100 | 8,896 | 83 |

SOURCE: National Science Foundation, *Academic Science/Engineering: R&D Funds FY 1985*, and unpublished data

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Industrial laboratories have historically performed about one-third of nonacademic basic research, and their efforts in this area are growing faster than those of any other sector. (See appendix table 5-1.) In 1985, industrial laboratories spent $2.85 billion on basic research activities, an increase of 65 percent in constant dollars over the 1980 level. In comparison, Federal laboratories increased their spending by 25 percent in constant dollars, and universities and colleges increased theirs by 18 percent.

The role of basic research within the various performing institutions varies widely. (See appendix table 4-7.) Universities, colleges, and other nonprofit institutions do more research than development. In contrast, basic research is only a small component of the overall R&D efforts of FFRDC's, government laboratories, and industrial firms.

The mix of institutions performing basic research in the United States is, by and large, typical of industrialized countries. The U.S. spends about the same share of its basic research dollars in industrial laboratories as does West Germany, and a somewhat smaller share than Japan. (See figure 5-1.) All the industrialized nations represented in figure 5-1 spend between one-half and two-thirds of their basic research funds in the higher education sector. The chief distinctive feature of the U.S. system is the high level of participation in basic research by the private nonprofit sector. Since this sector is growing more slowly in the U.S. than either academic R&D or industrial basic research, the patterns may in fact be converging.

## SCIENTISTS AND ENGINEERS IN ACADEMIC R&D AND BASIC RESEARCH

Research is only one of a number of activities that scientists and engineers pursue. For example, if they work in universities, they probably combine teaching with research; if they work in nonacademic settings, they may be primarily engaged in development. In either setting, scientists and engineers may spend more time on management than on research itself.

This section focuses on scientists and engineers whose main activity is the extension of knowledge—i.e., re-

[1]The actual estimate of 1,566 institutions includes the 566 universities and colleges that spent at least $50,000 on separately budgeted R&D in 1984 or granted a graduate science or engineering degree, 38 FFRDC's, and the 228 industrial firms that spent at least $10,000 on basic research in 1984. Also included are an estimated 444 nonprofit institutions (based on a 1973 survey) and 290 Federal intramural laboratories (based on a data base on laboratories maintained at the Technology and Information Policy Program at Syracuse University)

[2]National Science Foundation (1987b).

[3]National Science Foundation (1984).

Table 5-2. Distribution of R&D expenditures among industry performers, by size of company and character of work: 1985

| Size of company (no. of employees) | Research & development: Number of performers | Research & development: Thousands of dollars | Research & development: Percent of funding | Basic research: Number of performers | Basic research: Thousands of dollars | Basic research: Percent of funding |
|---|---|---|---|---|---|---|
| Total | NA | 71,137 | 100.0 | NA | 2,503 | 100.0 |
| Less than 1,000 | NA | 3,557 | 5.0 | NA | 447 | 17.9 |
| 1,000-4,999 | 775 | 4,395 | 6.2 | 73 | 315 | 12.6 |
| 5,000-9,999 | 185 | 3,175 | 4.5 | 34 | 138 | 5.5 |
| 10,000-24,999 | 191 | 10,332 | 14.5 | 65 | 490 | 19.6 |
| 25,000 or more | 127 | 49,678 | 69.8 | 56 | 1,113 | 44.5 |

SOURCE: National Science Foundation, *Research and Development in Industry, 1985*, and unpublished data

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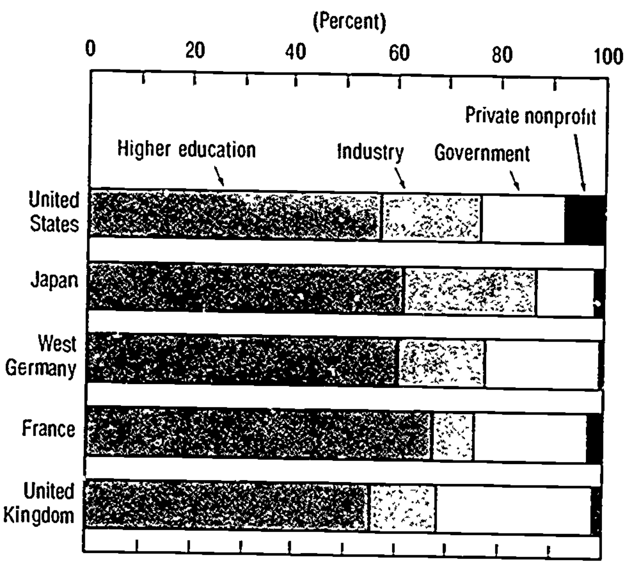
Figure 5-1.
**Basic research expenditures by performer, selected countries**




Note Data is for a year between 1980-84 depending on the country.
See appendix table 5-2

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search For data from universities and colleges, "researcher" applies to anyone whose primary or secondary work activity is research or development. This definition is based on the assumption that teaching and research are closely related in the university setting, that most researchers are doing some combination of both basic and applied research, and that the small amount of development activity performed (representing 4 percent of total R&D funding to universities and colleges) is closely tied to the growth of disciplinary knowledge. In nonacademic settings—where the distinction between research and nonresearch roles is clearer, and applied research is more closely tied to product development—"researcher" applies to anyone whose primary work activity is basic research.[4]

Two kinds of data are available on researchers: figures for all researchers, regardless of degree level; and figures on doctorate-level researchers alone. Both types of data are used in this section, often in comparison with each other.

## Number of Researchers

As mentioned in chapter 3, "Scientific and Engineering Workforce," more than 4 million scientists and engineers are employed in the United States in various occupations. Of the 1.2 million scientists and engineers in research or development (see appendix table 3-4), it is estimated that 213,300 were engaged in academic R&D or basic research as their primary work activity in 1986. (See appendix table 5-3.) Of these, 168,900 (79 percent) were employed by universities and colleges. The remaining 44,400 were engaged in basic research elsewhere, including 13,100 in industry, 17,200 in the Federal Government, and 9,400 in nonprofit institutions.[5] (See figure 5-2.) Less than one-half of these researchers held a doctorate degree.[6] (See appendix table 5-4.)

The proportion of doctoral researchers supported by Federal funds has been shrinking steadily, dropping from 56.0 percent in 1977 to 49.1 percent in 1985. (See table 5-3.)[7] The share receiving Federal support varies among employing institutions and S/E fields. Outside the Federal Government itself, the percent receiving Federal support is highest in nonprofit institutions (72 percent in 1985), and lowest in industry (14 percent).

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[4] The actual operational definitions used in compiling the tables for this section may vary from those described here. Such variations—specified in notes within the tables are caused by varying characteristics of data bases used.

[5] State and local governments employed 3,100 scientists and engineers in basic research, 1,900 were employed in other institutions.

[6] Note that this figure includes graduate students employed at universities in a research capacity.

[7] Note that this table includes researchers whose primary or secondary work activity was basic or applied research Thus the numbers are larger than those in appendix table 5-4.

Table 5-3. Ph.D. researchers,[1] by sector and Federal support status: 1977, 1981, and 1985

| Sector of employment | 1977 Number employed | 1977 Percent support | 1981 Number employed | 1981 Percent support | 1985 Number employed | 1985 Percent support |
|---|---|---|---|---|---|---|
| Total[2] | 113,255 | 56.0 | 136,945 | 53.4 | 145,918 | 49.1 |
| 4-year colleges and universities | 91,851 | 54.6 | 108,340 | 52.4 | 118,210 | 47.8 |
| Nonprofit | 5,540 | 82.2 | 7,334 | 79.0 | 7,002 | 71.5 |
| Industry | 9,014 | 21.3 | 12,623 | 15.4 | 12,336 | 14.0 |
| Federal Government | 6,850 | 99.9 | 8,648 | 100.0 | 8,370 | 100.0 |

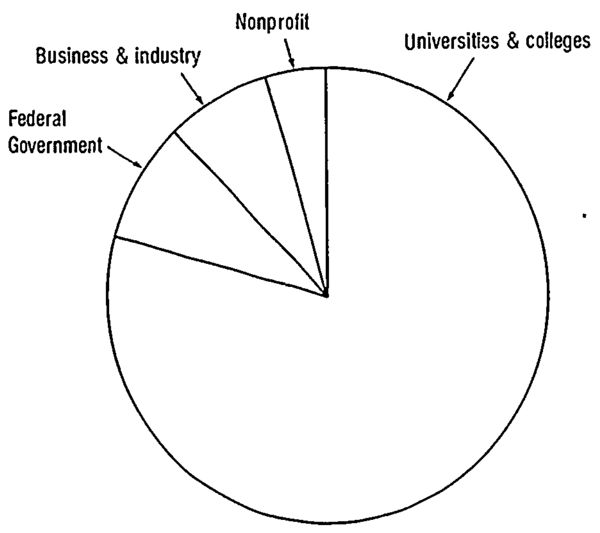
[1] "Researchers" are defined as 'nose primarily or secondarily employed in basic or applied research.

[2] Totals refer to these listed institution types only.

SOURCE: National Academy of Sciences, Survey of Doctorate Recipients, special tabulations

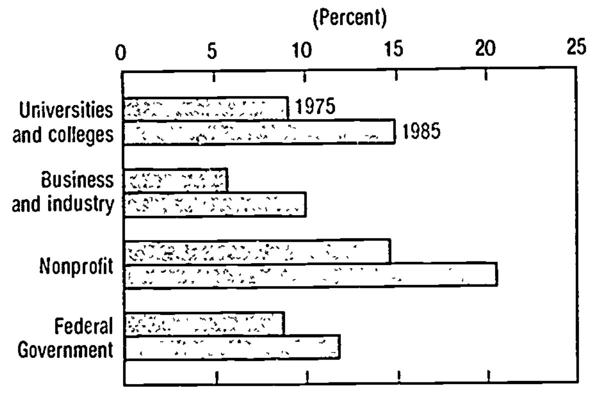
Science & Engineering Indicators—1987

Figure 5-2.
**Scientists and engineers in academic research and development and basic research, by employment sector: 1986**




See appendix table 5-3.
Science & Engineering Indicators — 1987

Figure 5-3.
**Women as a percent of doctoral scientists and engineers in research, by type of employer:**




See appendix table 5-5
Science & Engineering Indicators — 1987

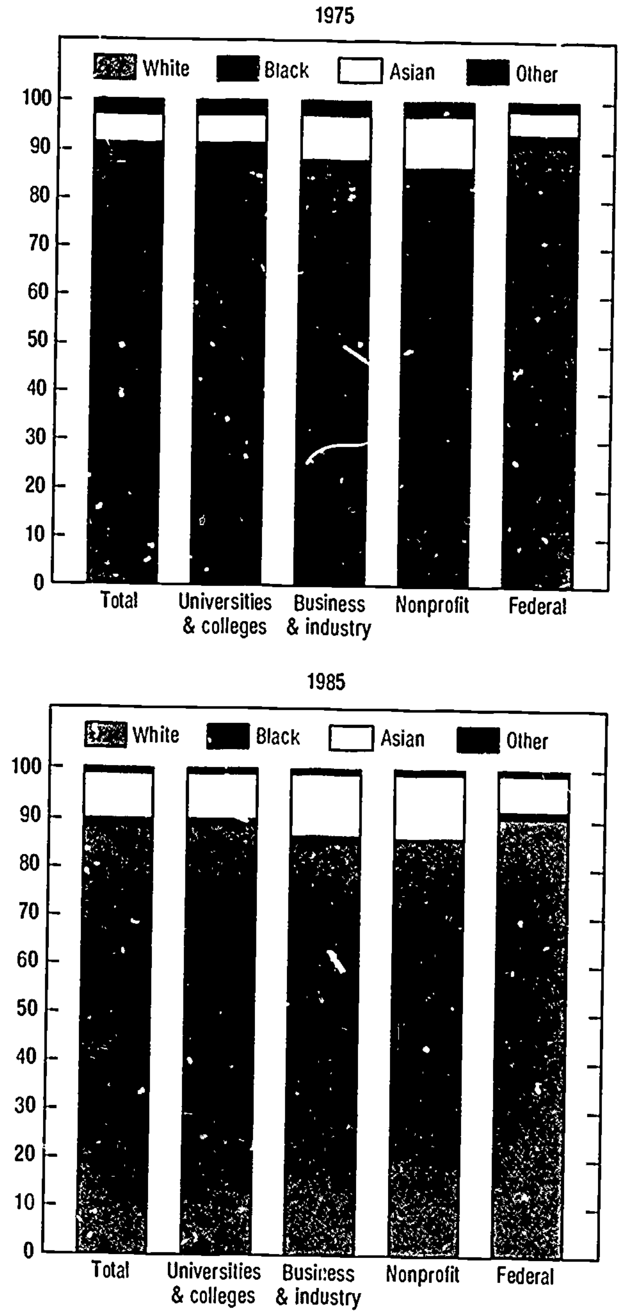
## Women Scientists and Engineers

The number of women with S/E Ph.D.'s in research has grown more slowly than the number in other S/E work activities. (See figure 5-3.) Nonetheless, the number of doctoral women in academic R&D and basic research nearly doubled between 1975 and 1985, and their proportion of all doctoral researchers rose from 9 percent to 15 percent during this time.

## Minority Scientists and Engineers

The number of blacks with S/E doctorates in academic R&D and basic research also nearly doubled between 1975 and 1985, and the percentage of blacks increased from 0.78 to 1.16. (See figure 5-4.) Blacks as a percentage of the total workforce in basic research in industry more than doubled. However, since black enrollment in science and engineering degree programs has slowed in recent years (see chapter 2, "Higher Education for Scientists and Engineers"), future gains are not likely to be as dramatic. Moreover, black participation in research is still low compared with the percentage of blacks in the total S/E population. (See figure O-14 in Overview.) In contrast, between 1975 and 1985, the percentage of doctoral Asians in research increased from 5.7 to 9.0, this percentage is higher than their representation among the total population of scientists and engineers

Figure 5-4.
**Doctoral S/E's in research, by race and employment sector: 1975, 1985**




See appendix table 5-6

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## Postdoctoral Positions

Postdoctoral positions are increasingly important as a first step in a research career. Between 1979 and 1985, the number of postdoctoral positions in all fields of science at doctorate-granting institutions grew at an average annual rate of 3.9 percent. At 4.8 percent, the 1984/5 increase was larger than average, bringing the total number of postdoctoral positions to 22,691. About two-thirds of these positions (15,264) were in the life sciences; another 20 percent were in the physical sciences. The number of positions increased most rapidly in the life sciences, which averaged a 4.6-percent increase per year between 1979 and 1985.[5]

Postdoctoral positions at U.S. institutions are attractive to foreign recipients of the U.S. doctoral degrees in S/E fields. Between 1972 and 1986, the number of foreign recipients of U.S. doctoral degrees who indicated firm plans to engage in further study at a U.S. institution increased threefold—from 251 to 744 individuals. In 1986, 28 percent of new foreign doctorate holders with firm plans indicated that they planned a period of postdoctoral study in the U.S. This was more than one-half (54 percent) of all those who planned to stay in the U.S. (See appendix table 5-7.)

## Retention Rates in Research Careers

The extent to which doctoral scientists and engineers either stay in research careers or move into other activities is an indicator of the research workforce's stability. Retention rates for careers in basic and applied research have in fact been on the increase since 1975. The percent of those who remained in these activities over the preceding 2-year period was somewhat higher in 1985 than it was in 1975. This was particularly true among engineers. (See table 5-4.) However, engineers showed greater year-to-year variability than did scientists. Over the past decade, scientists leaving research have been moving less often into teaching and management activities, and slightly more often into development. Between 1983 and 1985, development was the most common destination for engineers leaving research; teaching was the least frequent choice. (See appendix table 5-31.)

## Employment Sectors

In 1986, 79 percent of S/E researchers were employed at universities and colleges. (See figure 5-2.) This propor-

[5]See National Science Foundation (1987a), Table C-46.

**Table 5-4. Retention rates for research[1] careers: 1973/75-1983/85**

| Years | All fields | Scientists | Engineers |
|---|---|---|---|
| | Percent[2] | | |
| 1973-75 .............. | 72.2 | 74.2 | 60.1 |
| 1975-77 .............. | 70.9 | 72.8 | 59.4 |
| 1977-79 .............. | 63.9 | 67 | 45.7 |
| 1979-81 .............. | 75.7 | 77.3 | 63.6 |
| 1981-83 .............. | 72.9 | 75.3 | 59.1 |
| 1983-85 .............. | 75.6 | 76.5 | 69.8 |

[1] Research is defined as primary work activity in basic or applied research.
[2] Percent remaining in research over the preceding two-year period.

SOURCE National Academy of Sciences, Doctorate Records File, special tabulations

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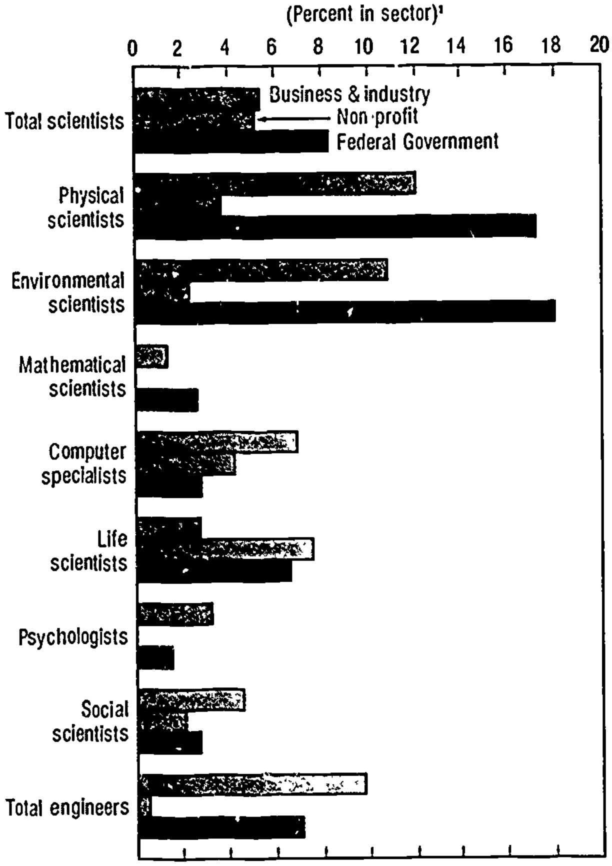
tion was nearly identical for both doctorate holders and other scientists and engineers. Some fields, however, have a higher representation of basic researchers outside the academic sector. (See figures 5-5 and 5-6.) For instance, 12 percent of all physical science researchers (and 21 percent of those with doctorates) work in industry; in contrast, industry employs only 5 percent of science researchers in all fields. Similarly, 17 percent of researchers in chemistry (30 percent of doctoral chemists) are employed in industry. Relatively large shares of earth scientists and computer specialists also work in industrial research. Environmental scientists are more likely to work for either a nonprofit institution or the Federal Government than are scientists in other fields.

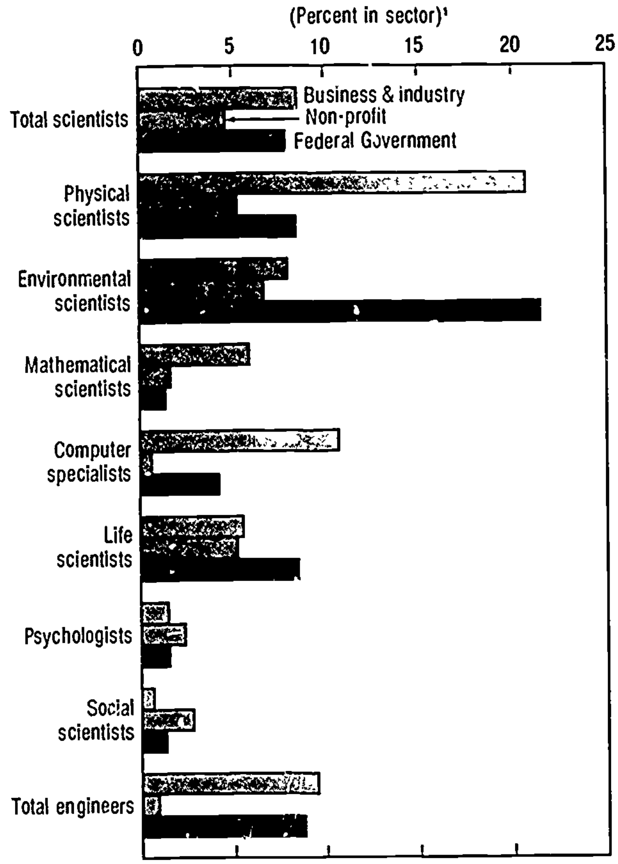
Engineering researchers are nearly twice as likely as scientists to work in the industrial sector. Among engineers, the Federal Government employs only 7 percent overall, but 37 percent of aeronautical and astronautical engineers (34 percent of those at the doctoral level), and 20 percent of materials engineers with doctorates. In engineering, the fields of concentration in industry and government are similar; in science, fields of concentration differ between industry and government.

Figure 5-5.
**Non-academic scientists and engineers in basic research, by sector and field: 1986**




[1]Percentage of all scientists and engineers in academic R&D and basic research.
See appendix table 5-3 Science & Engineering Indicators — 1987

Figure 5-6.
**Non-academic doctoral scientists and engineers in basic research, by sector and field: 1985**




[1]Percentage of all doctoral scientists and engineers in academic R&D and basic research.
See appendix table 5-4 Science & Engineering Indicators — 1987

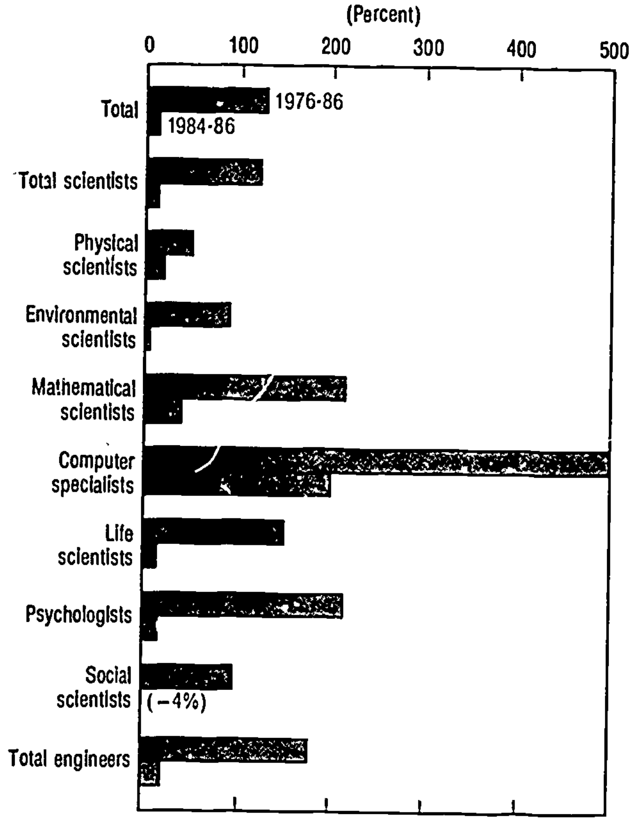
## Growth Patterns by Field

Over the last decade, the total number of scientists and engineers in academic R&D and basic research has more than doubled, and the number of doctorate holders has increased by 40 percent. (See figures 5-7 and 5-8.) Research engineers have increased faster than have research scientists (178 percent and 122 percent increases, respectively). At the doctorate level, the increases were 53 percent for engineers and 39 percent for scientists.

Among research scientists, computer specialists[9] are the fastest growing group, increasing fivefold between 1976 and 1986 (184 percent at the doctorate level). Since the number of computer specialists is still relatively

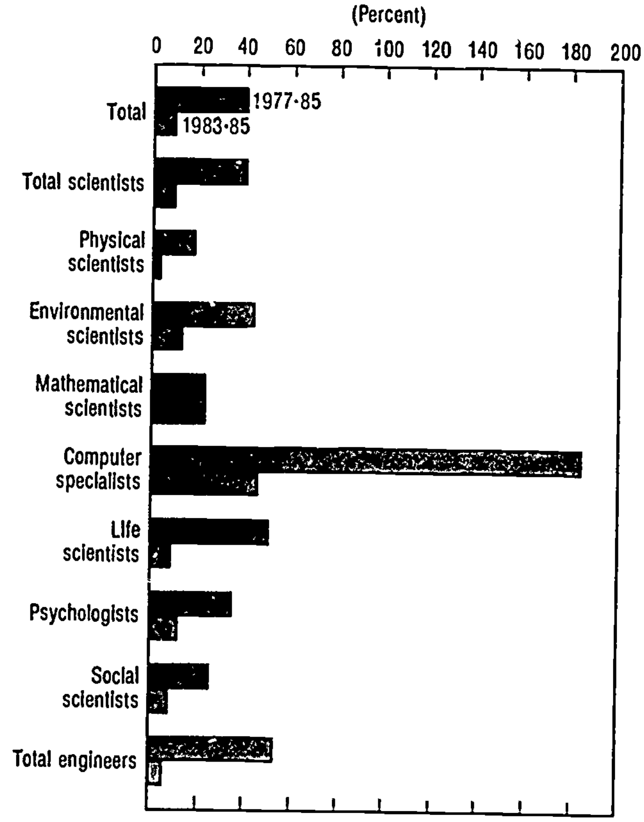
[9]Computer specialists are included among the fields of science rather than engineering.

Figure 5-7.
**Growth of S/E's in academic R&D and basic research, by field**




See appendix table 5-9. Science & Engineering Indicators — 1987

Figure 5-8.
**Growth of Ph.D. S/E's in academic R&D and basic research, by field**




See appendix table 5-10. Science & Engineering Indicators — 1987

small, however, this growth is not a major factor in the overall increase in scientists performing academic R&D and basic research. Researchers in the physical sciences show the lowest growth rates of any major disciplinary group for the decade: 18 percent overall and 26 percent at the doctorate level.

In the most recent 2-year period,[10] growth in the number of engineers in academic R&D and basic research was greater than that of scientists (19 percent versus 12 percent). At the doctorate level, however, the increase among engineers was less than among scientists (5.5 percent versus 8.9 percent). Chemical, industrial, and electrical/electronics engineers increased fastest—50 percent, 40 percent, and 29 percent, respectively, in total numbers. Among doctoral research engineers, mechanical, chemical, and civil engineering showed the fastest growth—98 percent, 39 percent, and 23 percent, respectively. Materials engineers in research decreased by 25 percent. In the most recent 2-year period, the total number of computer specialists engaged in research expanded by 20 percent (46 percent at the doctoral level).

## CROSS-SECTOR INTERACTIONS

An important measure of the strength of the U.S. research system is the extent of interaction among the various research-performing organizations—particularly between scientists and engineers in academia and those basic researchers in more mission-oriented sectors. Indicators of this interaction include mobility of researchers, coauthorship across sectoral lines, and citations among sectors. The following describes these indicators, and then discusses university-industry interactions.

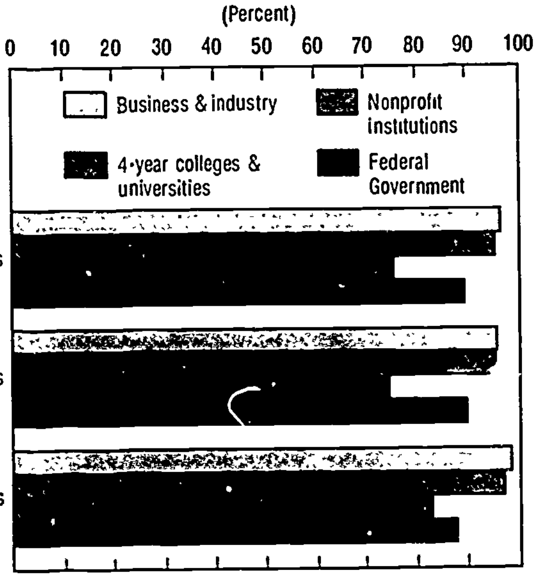
### Cross-Sector Mobility of Researchers

People are the principal carriers of ideas from one setting to another. The 2-year mobility rates shown in appendix tables 5-8, 5-11, and 5-12 indicate the flow of people among research-performing organizations. In general, over any given 2-year period, most scientists

[10]Alternate year surveys were conducted of all scientists and engineers and S/E Ph D's. Data for these two groups thus refer to the periods 1984-86 and 1983-85, respectively.

and engineers do not change their sectors of employment. (Note the estimated stability rates in figure 5-9.) For example, about 95 percent of researchers in either private industry or academia were still working in their respective sectors 2 years later. This level of stability has been about the same for the last decade. Among government researchers, the stability rate rose between 1973 and 1975 and between 1981 and 1983, but dropped between 1983 and 1985. Government researchers who change sectors are most likely to go to academia. nearly 5 percent did so between 1983 and 1985. (See appendix table 5-11.)

Figure 5-9.
**Percent of Ph.D. researchers who remained employed in the sector between 1983 and 1985**




See appendix table 5-8. Science & Engineering Indicators — 1987

Researchers in nonprofit organizations are most likely to move into another sector, probably because their jobs are most vulnerable to shifts in funding. In the past decade, about one-fourth of the researchers in nonprofits moved to another sector over any given 2-year period. Moreover, in both 1973-75 and 1981-83—periods when nonprofit institution basic research spending decreased—the percentage of researchers moving to another sector rose to one-third. During those periods, engineers were more likely to leave the nonprofit sector than were scientists. In 1973-75, nonprofit researchers were most likely to move into academic positions. During this time, an estimated 22 percent moved into academic positions. This represented 21 percent of scientists and 25 percent of engineers. In 1981-83, they were more likely (18 percent) to move to positions in industry. (See appendix table 5-11.)

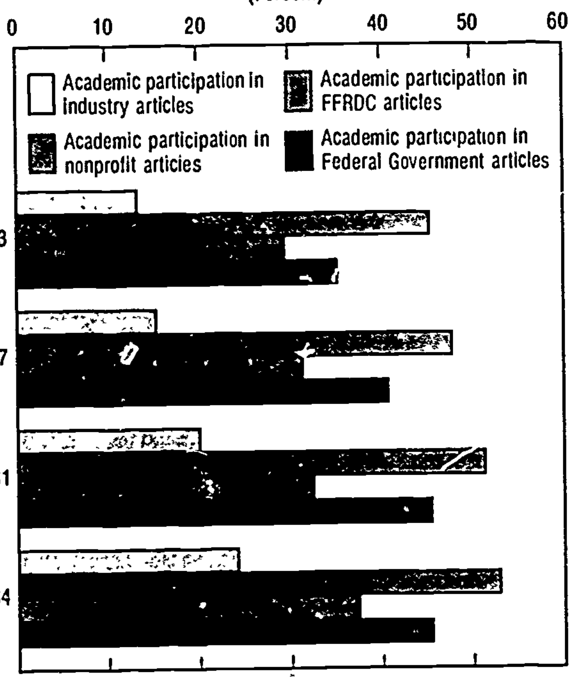
The migration rates for doctorate-level researchers between academia and industry are estimated to be small. (See appendix table 5-12.) Among scientists, a trend toward increasing proportions of academic researchers leaving for industry was reversed in 1983-85, when only 2.3 percent left for industry (compared with 2.8 percent between 1981 and 1983). On the other hand, the share of industry researchers moving to academia continued to climb, reaching 2.2 percent between 1983 and 1985.

Rates for engineers are harder to estimate because the numbers are small. However, the rate of cross-mobility for engineers seems to have dropped in the latest time period, with 1.6 percent of academic researchers moving to industry and only a fraction of 1 percent of industry researchers moving to academia.

## Cross-Sector Coauthorships and Citations

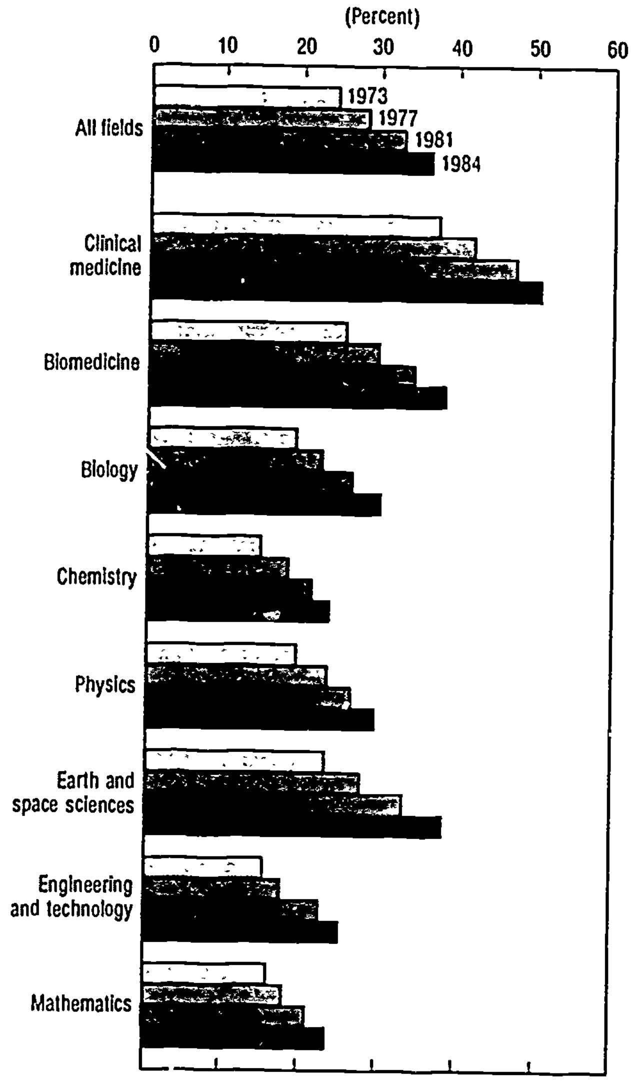
Research collaboration across sectors is on the rise, as indicated by the percent of U.S. publications with authors from more than one sector. (See appendix table 5-13 and figure 5-10.) Coauthorship rates in general are increasing across the fields of science and engineering (see figure 5-11), as are cross-sectoral coauthorships among all possible combinations of research-performing institutions. For instance, in 1973 only 19 percent of articles by authors in industry were coauthored with someone working in an-

Figure 5-10.
**Percent of articles by authors working in different sectors which were coauthored by academic authors**




See appendix table 5-13. Science & Engineering Indicators — 1987

Figure 5-11.
**Coauthored articles as a percent of all articles, by field of science: 1973, 1977, 1981, 1984**




See appendix table 4-36. Science & Engineering Indicators — 1987

other sector. (See appendix table 5-13.) In 1984, however, 36 percent were coauthored across sectors. Twenty-four percent of industry articles were coauthored with university researchers. The fastest growing areas of industry-university coauthorships in this period were biology and biomedicine; this may well reflect the rapid growth in the commercial significance of biotechnology. (See figure O-32 in Overview and appendix table 5-15.) Industrial coauthorship with FFRDC's and government laboratories also rose sharply.

In contrast, or perhaps as a consequence, the attention shown by researchers in one sector to articles published in another (as indicated by citation rates) has been dropping in most cases over the last decade. (See appendix table 5-14.) While the levels of citation from university authors to industrial authors remained relatively stable between 1973 and 1984, the attention given by industry to academia (using the citation indicator) dropped. The numbers show a significant increase in attention among nonprofit and Federal Government researchers toward articles from industry, as well as toward FFRDC's in the nonprofit case.

Examining the publications in detailed S/E fields illustrates the interdependence of research among the various sectors. For example, note the rapidly expanding research areas of transition-metal silicides and silicon molecular-beam epitaxy. Both of these areas are of strategic importance for the United States: the Soviet Union and Japan have active research efforts in each. Moreover, in each, the most active U.S. institutions are from different sectors. In transition-metal silicides, the most active institutions in 1984 were Bell Laboratories, IBM, RCA, the California Institute of Technology, and Stanford University. The most active institutions in 1984 in silicon molecular-beam epitaxy were Bell Laboratories, the Massachusetts Institute of Technology, the State University of New York at Albany, and the University of California at Los Angeles.[11]

## University-Industry Contacts

Concern with the international competitive position of U.S. industry has focused attention in particular on university-industry contacts. As noted in chapter 4, "Resources for R&D and Basic Research," industry support is the fastest growing source of support for university research, although it is still a small percentage of the total. These data, along with information on coauthorship and cross-citation, suggest that the level of contact between industry and academia may be increasing.

Research itself is only one reason for university-industry contact. Educational ties may be more important in the long run. In a 1984 survey, a large share of doctorate-granting institutions reported research ties with industry (91 percent of public and 65 percent of private), but among all the institutions responding, only 18 percent reported research contacts.[12] The most widespread ties were joint meetings and equipment sharing (reported by more than 70 percent of responding campuses), followed by direct educational contacts: scholarship/loan programs and credit and noncredit courses for employees. (Between 40 and 50 percent of responding campuses were involved in these.) Lastly, 15 to 20 percent of universities reported jointly sponsored degree programs, shared staff arrangements, or research contacts.

A similar survey among firms in Michigan produced the distribution of contacts noted in appendix tables 5-16 and 5-17. Attending conferences appears as the most frequent form of contact (as it did in the survey among universities), and research contracts involved only a

[11] Unpublished data provided by the National Science Foundation, Division of International Programs.
[12] American Council on Education (1985)

small proportion of the firms. In general, the larger the company, the greater its range of university relations. Also, university-industry interaction is related to company life cycles. Companies at the start-up stage were most likely to use technical services, employ faculty consultants, and have a variety of other professional interactions with nearby campuses. Companies at the stage of rapid growth were most likely to recruit graduates, sponsor internships, and send staff to conferences. Companies of stable or declining growth had the lowest levels of university interaction.[13]

Numerous and varied Federal programs have tried to encourage university-industry interaction over the years.[14] In the 1980's, many States also initiated efforts to encourage contacts between local universities and industrial firms. Much of the encouragement is for educational activities of the sort mentioned above, but some of the efforts are focused on research. Surveys by the National Governors' Association and the U.S. Congress, Office of Technology Assessment, identified about 50 of these efforts, spread across 29 States.[15] More than two-thirds of the research initiatives consisted of matching grants for industrial funding of university research, sometimes involving collaborative work. Cumulative 1980-84 funding in these programs was estimated at $350-450 million.

*Faculty Consulting*. Academic R&D contributes to industrial innovation through direct transfer of information in the form of technical services and formal or informal consulting relationships. An estimated 80 percent of faculty members at U.S. universities and colleges have consulted for an off-campus client at some point in their careers, although less than 20 percent report having done "a great deal" of it.[16] About 90 percent of engineers have had such experience; at less than 70 percent, mathematicians and statisticians are least likely to have had this experience. Every type of campus is involved. About three-fourths of the faculty at baccalaureate institutions report consulting experience, ranging up to nearly 90 percent of those at select research institutions.

There is a special relationship between small businesses and teaching institutions. In a 1984 survey, faculty at comprehensive universities, colleges, and baccalaureate institutions were much more likely to report that their last clients were small businesses than were researchers at research universities or engineering schools. These discrepancies are particularly great in the environmental sciences. (See appendix table 5-18.)

*Research Contacts*. The distribution of industry support among fields of academic science is not known; about one-half, however, is apparently spent in engineering.[17] In a 1984 survey, industry respondents ranked the relevance of research in the various science fields to technical change in their lines of business. Computer science and metallurgy headed the list, followed by materials science and chemistry.[18]

Industrial support of university research in biotechnology has received considerable attention in recent years, but a 1985 survey shows that this support has not yet reached the relative importance that it has in chemistry and engineering.[19] Twenty-three percent of respondents working in the "new biotechnologies" were principal investigators on projects sponsored by industry, as compared with 43 percent of those in chemistry and engineering. Industry supplied 7.4 percent of the research funds received by biotechnology faculty, as compared with 32 percent of the funds received by chemistry and engineering faculty.

*University Entrepreneurship*. Another new feature of the relationship between universities and commerce is academic entrepreneurship, which involves both individual faculty members and universities themselves. Several developments have influenced this trend, including changes in Federal patent laws and the emergence of the biotechnology industry.

In 1980, Federal patent law was altered to allow universities and small businesses to retain title to inventions resulting from Federally sponsored research projects. This change provided a new incentive for the formation of businesses based on university inventions. The effects of this change in the law are expected to appear only in the long term; further, they will be difficult to separate from other changes in the academic environment.[20]

The level of patenting activity of U.S. universities and colleges has increased over the past 2 decades (see appendix table 5-19), although academic patenting remains only a small share of the total. The rate of increase in patents granted between 1980 and 1985 was more than double the rate of increase in the preceding 5 years; it was somewhat less, however, than the rate of increase for 1970-75. The most active patent classes are in the biomedical area: bio-affecting drugs, molecular biology and microbiology, and surgical inventions.

Another sign of the involvement of academia in the commercial sphere is the appearance of spin-off firms founded by university scientists. Despite the attention devoted to a few examples such as Cetus and Genentech, there are indications that this phenomenon is concentrated in a few universities and involves only a handful of firms.[21] A 1985 survey found that only 8 percent of faculty in biotechnology fields held equity in a company whose products or services were based on their research.[22] Similarly, a study of the "Cambridge phenomenon" has

[13] Pelz and Hart (1986).

[14] For a description of the National Science Foundation's array of programs in thi[illegible] Bloch and Kruytbosch (1986), pp. 51-57.

[15] National G[illegible]ciation (1983) and (1985); and U.S. Congress, Office o[illegible]ment (1983) and (1984). In extracting State-sponso[illegible]as from these documents, research was defined [illegible] of knowledge. Basic and applied research we[illegible]ose small amounts of development funding that [illegible]ated from research.

[16] Darknell a[illegible].

[17] *Engineering Ed*[illegible])

[18] Nelson (1986), p. 187.

[19] Blumenthal, et al. (1986), p. 1362.

[20] A study of university patenting policies before and after the change in the law was conducted by the Society of University Patent Administrators. A copy of the report is available from Frederic H. Erbisch, Director of Research Services, Michigan Technological University, Houghton, MI 49931.

[21] Peters and Fusfeld (1983).

[22] Blumenthal, et al. (1986), 1364.

1[illegible]

shown that most of the high-technology development associated with that university town has been generated through a chain of spin-offs from firms, not by spin-offs directly from the university.[23]

## INTERNATIONAL CONTACTS

Science and engineering research has always been an international activity. For centuries, students have traveled to the world's scientific centers for training and maintained contact with their teachers after returning home. There is an equally strong tradition of researchers with common interests collaborating across national boundaries. Scientific knowledge, once created, has been shared. The following presents indicators of U.S. participation in the international world of science.

The evidence presented here points to a changing pattern. The U.S. educational system is granting an increasing number of doctorate degrees to foreign nationals, and larger proportions of these degree recipients are electing to stay in the U.S. to pursue their careers. At the same time, U.S. citizens with new doctoral degrees are going abroad at the same rates as for the past decade. At the senior level, U.S. researchers are collaborating more internationally. Yet world science is paying somewhat less attention to U.S. science (at least as indicated by citations) than it has in the recent past.

### Young Researchers

In 1986, a larger share of doctoral recipients in the United States were foreign citizens than at any time in the last 10 years, and a larger share of them had plans to stay and work in the United States. In 1975, 16 percent of doctorate recipients were foreign nationals, as compared with 21 percent in 1986. (See appendix table 5-20.) Of those with firm postgraduation plans, 29 percent in 1972 planned to stay in the United States, but 52 percent planned to do so in 1986. (See appendix table 5-7.) Of this latter group, 54 percent were staying for postdoctoral research, 26 percent for academic employment, and 17 percent for industrial employment. In the physical and biological sciences, the largest percentages were staying for postdoctoral study; in engineering, mathematics, and computer science, the largest percentages were going directly into academic or industrial employment.

One-half as many S/E doctorate recipients who were U.S. citizens (214) planned to go abroad for postdoctoral study in 1983 as the number of foreign recipients who planned to stay here (434). (See appendix table 5-21.) The percentage of U.S. citizens going abroad for postdoctoral study has fluctuated over the years. It reached its high point in 1971, when 2.4 percent went abroad. In recent years, the share has been much lower, about 1.5 percent. In psychology, the trend has clearly been down; in other fields, such as agriculture and the social sciences, the share seems to be rising.

[23]*The Cambridge Phenomenon* (1985).

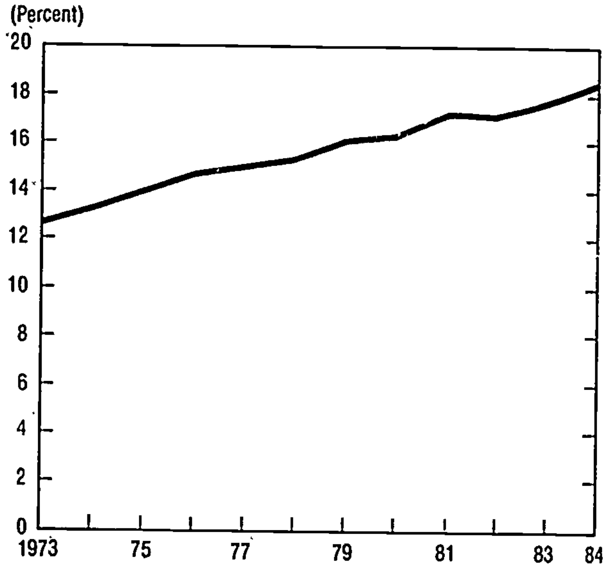
### International Collaboration

International collaboration is playing an increasingly large role in the production of scientific knowledge. One sign of this trend is the increase in academic exchange visas granted by the U.S. Government. In 1986, 102,854 foreign nationals were granted visas to visit universities in the United States; this was up 15 percent over 1985, and up 52 percent since 1978. (See appendix table 5-22.)

This is also demonstrated by cross-national coauthorships in the research literature. U.S. articles that were internationally coauthored have made up a larger share of the literature every year over the past decade. (See figure 5-12.) In 1984, 18 percent of papers with authors from more than one institution involved international collaboration, as compared with 13 percent in 1973. International collaboration increased fastest in the fields of engineering and technology (a 58-percent increase in the share from 1973 to 1984) and physics (a 48-percent increase). (See appendix table 5-23.) Researchers at FFRDC's were most likely to be involved in international coauthorship in 1984, followed by those in universities and industry. (See appendix table 5-24.) More than 25 percent of publications from FFRDC's were internationally coauthored, as compared with 18 percent for private firms and 16 percent for universities. Industry's cross-national collaboration rate is increasing more slowly than the rates in other sectors.

The increase in U.S. international collaboration has been modest compared with that in other major scientific

Figure 5-12.
**Internationally coauthored articles as a percent of all institutionally coauthored articles[1]**




[1]Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. The last four years use over 3,500 journals of the 1981 *Science Citation Index* Corporate Tapes. See appendix table 5-23.

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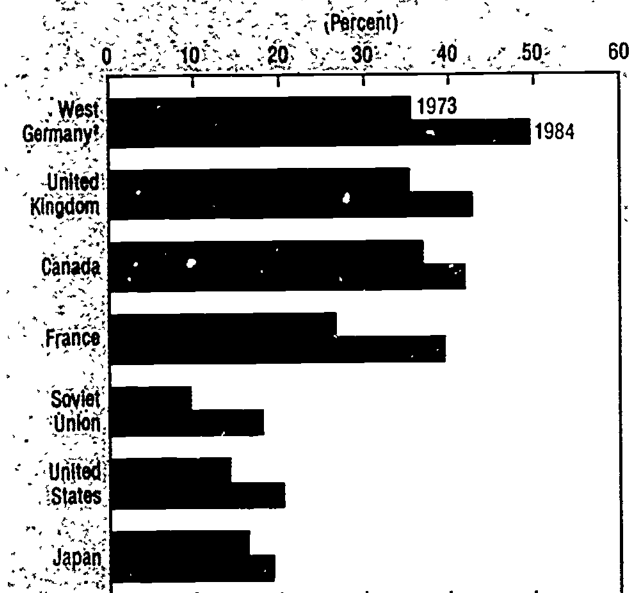
nations; further, the U.S. level of international collaboration is relatively low. (See figure 5-13.) In West Germany, the United Kingdom, France, and Canada, from one-third to one-half of institutionally coauthored publications are coauthored with researchers from other nations, as compared with about one-fifth in the United States. The U.S. percentage is similar to that for the U.S.S.R. and Japan.

### Publications

The share of the world's literature that comes from the United States has been stable for some time at 35 percent,[24] as have the U.S. shares of world publications in the various S/E fields. The fields in which the U.S. produces the largest share of the world's publications are earth and space sciences (41 percent), clinical medicine (41 percent), engineering and technology (40 percent), and biomedicine (39 percent). (See appendix table 5-26.) The distribution of articles by subfield appears in appendix table 5-27.

[24] The slight drop in the percentage between 1980 and 1981 is the result of an enlargement of the data base.

Figure 5-13:
**Internationally coauthored articles as a percent of all institutionally coauthored articles, by country[1]**




[1] The 1973 data are based on articles, notes, and reviews in over 2,100 influential journals carried on the Corporate Tapes of the 1973 *Science Citation Index* of the Institute of Scientific Information. The 1984 data are based on over 3,500 journals in the 1981 *Science Citation Index*.

[2] When an article is authored by scientists and engineers from more than one country, that article is counted once for each country involved.

See appendix table 5-25.

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### Cross-National Attention

While international collaboration in the form of coauthored papers is increasing, a closer look at the literature indicators suggests two further developments in the flow of information between U.S. and foreign researchers.

First, U.S. authors are paying increasing attention to the published work of foreign authors. Between 1974 and 1984, references in U.S.-authored S/E articles to foreign-authored articles increased from 23 percent to more than 29 percent of all references. (See figure O-21 in Overview and appendix table 5-28.) This pattern holds across all broad S/E fields. It is most marked in mathematics, where the proportion of references to foreign articles almost doubled over the decade.

Second, while U.S. researchers are increasingly scanning foreign literatures, world S/E authors are paying slightly less attention to U.S. published work. (See appendix table 5-29.) The U.S. literature published in 1982 was cited only about 83 percent as frequently as one would expect on the basis of its volume—down from 96 percent in 1980.[25] U.S. physics, chemistry, and earth and space sciences received the most attention from abroad, more than 90 percent of what would be expected based on the volume of the 1982 published literature.

### A Case Study in International Collaboration

The earth and space sciences illustrate the trends toward internationalization outlined above. These fields also show the growing levels of international activity as demonstrated by shared facilities—for example, those provided by the Deep Sea Drilling Project (DSDP), the world's largest international collaborative venture.

Both institutional and international coauthorship have been rising in the earth sciences. Institutional coauthorship rose from 23 percent of all articles in 1973 to 39 percent in 1984. (See appendix table 4-36.) Internationally coauthored articles have risen from 23 percent of all institutionally coauthored articles in 1973 to 34 percent in 1984. (See appendix table 5-23.) Among the nine most active nations in these fields, the U.S. shows the second highest level of in-country institutional coauthorship. (The highest level is in the Soviet Union.) The U.S., however, is also the most frequent partner of the other active countries when they coauthor internationally.[26]

One factor contributing to the increase in international coauthorship in these fields is the need to share very expensive research equipment. For instance, special drilling ships and equipment are needed to drill into the ocean floor and retrieve geological information. In 1974,

[25] Although this measure of world attention to the 1982 U.S. literature can be expected to rise somewhat when 1985 and 1986 citing literature are added to the data base, it is still lower than the comparable figure for the 1980 literature (that is, the relative citation ratio .85 for the 1980 literature as cited by only 1981 and 1982 papers).

[26] Computer Horizons, Inc. (1986).

the National Science Foundation's ocean drilling program—which operated such a ship—was internationalized. The $40 million annual operating costs of the new Deep Sea Drilling Project are now shared among six partner countries, including the United Kingdom, West Germany, Canada, Japan, and France. Scientists from member countries propose shipboard projects to a selection panel, and share the ship and its facilities on its research voyages.

Areas of research in which DSDP results are reported show higher levels of international coauthorship than appear in the earth sciences as a whole. The 10 areas listed in appendix table 5-30 were identified in a bibliometric data base as some of the ones where results of DSDP projects are most prominent.[27] U.S. authors publishing in these areas showed noticeably higher rates of international coauthorship in 1983 and 1985 than the rates for the earth sciences as a whole in 1982. These data are consistent with the notion that the activities of the Drilling Project itself encourage international collaboration.

[27]The areas of research were created through co-citation clustering of the *Science Citation Index*. Areas where the term "deep sea drilling" appeared frequently in article titles were chosen for analysis. The set of research areas is thus intended to illustrate the collaboration rates in DSDP research areas, and not to be either comprehensive or representative.

## REFERENCES


American Council on Education, "Campuses Weld the Corporate Link," *Educational Record*, Spring 1985.

Bloch, E. and C. Kruytbosch, "The NSF Role in Fostering University-Industry Research Relationships," *IEEE Transactions on Education*, Vol. E29, May 1986.

Blumenthal, D., et al., "University-Industry Research Relationships in Biotechnology: Implications for the University," *Science*, 232, June 13, 1986.

*The Cambridge Phenomenon: The Growth of High Technology Industry in a University Town* (Cambridge, England. Segal Quince Wicksteed, 1985).

Computer Horizons, Inc., *Science Indicators Literature Data Base*, Indicator Series #6: International Coauthorship (data base prepared under contract to the National Science Foundation, 1986).

Darknell F. and D. Nasatir, "Consulting as a Science Indicator," final report to the National Science Foundation under Grant SRS-8307778, May 1987.

*Engineering Education*, special issue, "Engineering College Research and Graduate Study," Vol. 77, No. 6, March 1987.

National Governors' Association, *Programs for Innovative Technology Research in State Strategies for Economic Development* (Washington, DC: December 1985).

National Governors' Association, "Technology and Growth: State Initiatives in Technological Innovation," final report of the Task Force on Technological Innovation (Washington, DC: October 1983).

National Science Foundation, "Academic Science/Engineering: Graduate Enrollment and Support, Fall 1985," SRS 87-D5 (Washington, DC: National Science Foundation, 1987a).

National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1985, 1986, 1987*, Volume XXXV (Washington, DC. National Science Foundation, 1986).

National Science Foundation, *Federal Funds for Research and Development. Fiscal Years 1986, 1987, 1988*, Volume XXXVI (Washington, DC. National Science Foundation, 1987b).

National Science Foundation, *Research and Development in Industry* (Washington, DC. National Science Foundation, 1984).

Nelson, R.R., "Institutions Supporting Technical Advance in Industry," *American Economic Review*, Vol. 76, No. 2, May 1986.

Pelz, D.C., and S.L. Hart, "Business Firm Study: Basic Data on Relations with Universities" (Ann Arbor: University of Michigan, 1986).

Peters, L. and H.I. Fusfeld, "Current U.S. University-Industry Research Connections," in National Science Board, *University-Industry Research Relationships: Selected Studies*, NSB 82-2 (Washington, DC: National Science Foundation, 1983).

U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development: Encouraging High Technology Development—Background Paper #2*, OTA-BP-STI-25 (Washington, DC: February 1984).

U.S. Congress, Office of Technology Assessment, *Technology, Innovation and Regional Economic Development Background Papers. Census of State Government Initiatives for High Technology Industrial Development*, OTA-BP-STI-21 (Washington, DC: May 1983).

# Chapter 6
# Industrial Research and Technological Innovation

# Industrial Research and Technological Innovation

## HIGHLIGHTS

- *Industry employs about four-fifths of all engineers in the United States and one-half of all scientists.* This includes more than three-quarters of all computer specialists and more than one-half of all environmental scientists. From 1976 to 1986, employment of industrial scientists and engineers increased by 8 percent per year, in spite of a major recession during this period. (See pp. 103-104.)
- *Expenditures for industrial research and development (R&D) are growing.* Total industrial expenditures for R&D are estimated at $91 billion for 1987; this represents 73 percent of all R&D expenditures in the United States. From 1980 to 1987, the average annual increase in industrial R&D expenditures was 5.8 percent in constant dollars. (See p. 104.)
- *Private industry has funded more than one-half of all industrial R&D every year since 1968, and now funds nearly two-thirds of the total.* From 1980 to 1985, the annual rate of increase in company R&D spending was 5.5 percent in constant dollars. Only a 3-percent increase is estimated from 1985 to 1986, and a 2-percent increase from 1986 to 1987. (See pp. 104-105.)
- *The rate of increase of Federal funds for industrial R&D has slowed after a period of rapid growth.* From 1980 to 1985, Federal funds for industrial R&D rose at an annual rate of 7.8 percent in constant dollars. The estimated increase for 1985 to 1986 is 14 percent; however, for 1986 to 1987, the estimated rate of increase dropped to 3 percent. (See p. 105.)
- *As a group, nonmanufacturing industries that perform R&D showed considerable employment growth from 1975 to 1985.* During this time, employment rose only slightly in high-technology manufacturing. Employment declined in other manufacturing. (See pp. 105-106.)
- *Between 1980 and 1985, R&D expenditures increased especially rapidly in high-technology manufacturing industries.* The growth rate was 7.6 percent per year in constant dollars, compared with 2.4 percent per year in other manufacturing and 3.9 percent per year in nonmanufacturing. This increase in high-technology spending was largely due to Federal expenditures for defense R&D in the aircraft and missiles industry. Such expenditures grew annually by 9.3 percent in constant dollars during this period. (See p. 106.)
- *The decline in patenting by Americans has stopped, but foreign patents in the U.S. continue to increase.* The filing of successful patent applications by Americans peaked in 1969 and reached a low point in 1983, with a slight (14 percent) recovery from 1983 to 1986. Small companies receive about 12 percent of U.S. domestic patents; universities receive about 2 percent. Successful patent applications by foreigners have increased, currently accounting for 46 percent of all U.S. patents. (See pp. 106-108.)
- *Japanese patenting in the United States has increased considerably in recent years, especially in high-technology fields.* From 1975 to 1986, the Japanese share of U.S. patent grants increased from 8 to 19 percent. This increase offset the drop in the American share, particularly in the transportation equipment and office, computing, and accounting machine fields. In a sample of 13 narrow high-technology fields, the number of Japanese patents increased in all fields, and the Japanese share increased in all but one. Furthermore, although the number of American patents increased in 7 fields, the American share decreased in all 13 fields. (See pp. 108-110.)
- *Small high-technology businesses have experienced a much higher rate of growth during the last decade than has either small business employment overall or total employment.* In some high-technology industries, there was a strong trend for successful small firms to leave the pool of small businesses, either through internal growth, merger, acquisition, or corporate takeover. Consequently, firms representing 16 percent of small business employment in 1980 in the office, computing, and accounting machine industry had become parts of medium-sized or large firms by 1984. (See pp. 111-114.)
- *The pool of capital managed by venture capital firms was almost seven times as large in 1986 as it was in 1978.* Venture capital is an important source of funds in the expansion of small high-technology companies. In 1986, new funds made available to venture capitalists reached $4.5 billion. Throughout the early 1980's, disbursements by venture capitalists lagged behind new commitments of funds, indicating a growth of the capital still available for investment. Firms producing computers and computer-related goods and services have been popular with venture capitalists, both for direct venture capital investments and for venture-backed offerings of stock. (See pp. 114-115.)
- *Small business has been particularly important in the biotechnology industry.* Approximately two-thirds of the firms reporting activity in biotechnology employed fewer than 1,000 people; about 75 percent of these were privately held firms. These firms were concentrated in genetic engineering and in biotechnology equipment. There are preliminary indications that new firms entering the biotechnology field are shifting from the core areas of genetic engineering and immunology to such specializations as equipment, cell culture technologies, and animal biotechnology. (See pp. 115-116.)

In the United States, as in many other Western countries, private industry is the source of technological innovation and the site of most R&D activity aimed at such innovation. This sector is also the principal employer of scientists and engineers.

In terms of expenditures, private industry performs about 73 percent of the Nation's R&D. (See figure 6-1.) In the other four large free-market countries (Japan, West Germany, France, and the United Kingdom), industry's share of the total national R&D is lower, however, that in Japan and West Germany is beginning to approach the U.S. level. As a source of funds, private industry supports about one-half of all R&D conducted in the United States. (See figure 6-1.) While this is a high level, it is exceeded by countries like West Germany and Japan that do not have such large amounts of government-supported military R&D.

Current U.S. policy interest is centered on sustaining economic growth, and especially on fostering the international competitiveness of U.S. industries in both high- and low-technology areas. Industrial competitiveness affects such broad economic issues as job creation and retention, the rate of inflation, the balance of payments, and economic growth. Federal policy attempts to encourage industrial growth and competitiveness in several ways. It seeks to promote technological development through direct support and tax incentives for R&D expenditures, and through measures to control inflation, improve capital formation, improve the patent system, and remove unnecessary Federal regulations. Thus, Federal support for basic research—principally at universities and colleges, but also at agricultural experiment stations, hospitals, and Federal and private laboratories—supplies part of the knowledge base for new technology. Support for science and engineering (S/E) education provides the necessary personnel, again primarily by way of the university and college sector. Finally, regulatory and patenting reforms are intended to improve the conditions and incentives for increased industrial science and technology (S/T) activities.

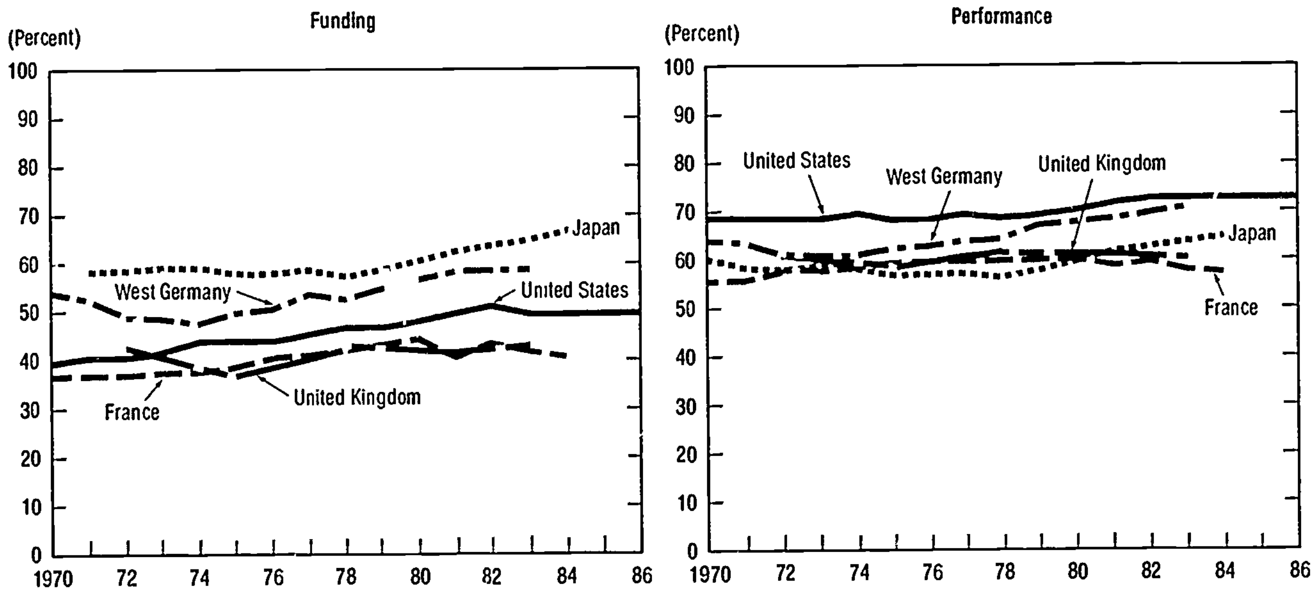
This chapter discusses indicators of recent trends in industrial S/T resources and activities related to technological innovation. "Input" indicators such as S/E personnel, R&D expenditures, and venture capital outlays are presented. This is followed by discussions of trends in patenting, the role of small business in innovation, and selected measures of technological innovation.[1]

## SCIENTIFIC AND ENGINEERING PERSONNEL IN INDUSTRY

The past decade has seen dramatic changes in the occupational and industrial distribution of the science, engineering, and technical workforce in industry. (See chapter 3, "Science and Engineering Workforce," pp. 55-58.) The principal broad features of these changes are. (1) the rapid expansion of the nonmanufacturing sector which primarily accounted for the increase in S/E employment during the decade, and (2) the increasing proportion of scientists and engineers in the relatively static

[1]See also chapter 7, "The International Markets for U.S. Technology," for additional information on the competitiveness issue

Figure 6-1.
**Industry funding and performance of R&D, as a percent of total R&D, in selected countries**




See appendix table 6-1.

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total employment growth in the manufacturing industries, reflecting an increasingly "hi-tech" workforce in this sector.

Industry employs about four-fifths of all engineers in the United States, and about one-half of all scientists.[2] More than three-quarters of all computer specialists are in industry, as are three-fifths of physical scientists and more than one-half of all environmental scientists. R&D is the primary work activity of about one-fourth of all scientists and engineers in industry. While scientists are concentrated more in research than in development, the opposite is true for engineers. Many scientists and engineers also engage in other S/T-related activities, such as R&D management, teaching, design, testing, production, sales, and inspection. (See appendix table 3-4.) Thus, trends in industrial S/E employment reflect shifts in the amount and distribution of S/T-related work performed by industry.

Over the 1976-86 period, employment of scientists and engineers in industry grew—despite a major recession—at a rate of 7 percent per year. (See chapter 3, "Science and Engineering Workforce, p. 56.) This suggests not only that employment opportunities are increasing in science and engineering as compared with other fields, but also that industry is becoming more and more reliant on science and technology to improve its products, production processes, and services.

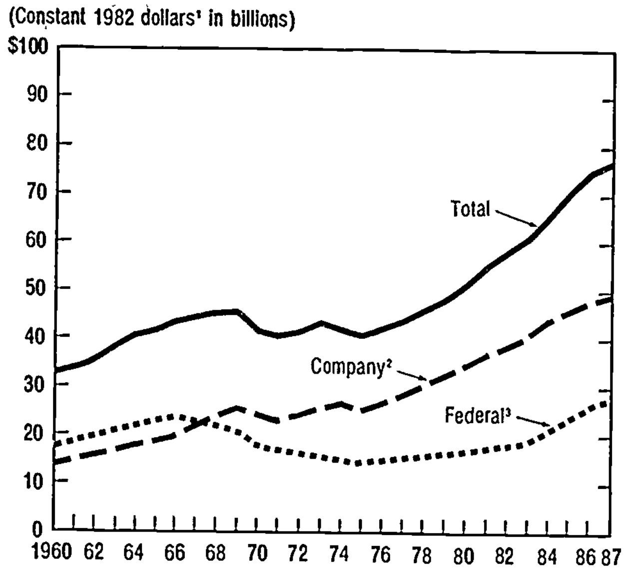
In 1986, industry employed almost 800,000 scientists and 1,800,000 engineers. Employment of scientists was dominated by computer specialists, while electrical/electronics and mechanical engineers were dominant among engineers. (See appendix table 3-16.) Since 1976, computer specialists have shown the greatest growth rate, accounting for more than one-half of total employment growth in the sciences. By 1986, they made up 40 percent of all scientists in industry. Mathematical scientists, many of whom work in computer-related areas, were the second most rapidly increasing group. Within engineering, employment of civil engineers showed the most rapid growth.

## EXPENDITURES FOR RESEARCH AND DEVELOPMENT IN INDUSTRY

Trends in constant-dollar funds spent on industrial R&D are indicators of the level of R&D activity in industry. Funds for industrial R&D come almost exclusively from two sources: private industry itself and the Federal Government.[3] Total estimated current-dollar expenditures for industrial R&D have increased markedly in the last several years, with $85.7 billion estimated for 1986 and $90.7 billion for 1987. (See figure O-28 in Overview.) This increase represents a 10.7-percent per year growth rate from 1980 to 1987 in current dollars. In constant-dollar terms, total R&D funding in industry has risen every year from 1975 to 1987 at an average rate of 5.4 percent per year, between 1980 and 1987, it has grown 5.8 percent per year. The 1986-87 increase, however, is estimated at only 2.5 percent. (See figure 6-2.)

Total R&D funding in the United States is estimated at $124.3 billion in 1987, by this measure, industry performs 73 percent of the Nation's R&D. About 76 percent of funding for industrial R&D is for development, while development is only 36 percent of R&D expenditures in all other sectors combined.

Figure 6-2.
**Expenditures for industrial R&D, by source of funds**




¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars.
²Includes all sources other than the Federal Government.
³Includes Federally Funded Research and Development Centers administered by industry.
Note: Preliminary data are shown for 1985 and estimates for 1986 and 1987.
See appendix table 6-2. Science & Engineering Indicators — 1987

### Trends in Company Funding

Both Federal and State Governments have been active in encouraging technology investments by private companies.[4] For example, the Federal Government has taken measures to stimulate the economy, grant special tax credits for R&D, and clarify the restrictions on R&D consortia involving competing companies. Testifying to the success of such efforts, company funding in 1987 was

²See National Science Foundation (1985).

³The small amount of funding from other sources, such as State Governments, is combined with private company funding in the following discussion. Some companies perform "independent research and development" (IR&D), i.e., in-house R&D intended to better prepare the companies to bid on National Aeronautics and Space Administration or Department of Defense projects. Some of these expenditures are later reimbursed by the agency as overhead charges allocated to contracts. In this chapter, IR&D expenditures are counted as company-funded R&D.

⁴See U.S. Congress, Office of Technology Assessment (1984) and National Governors' Association (1983). Trends in collective industrial research in the United States and some other countries are studied in Haklisch, Fusfeld, and Levenson (1984).

estimated to be 64 percent of all R&D expenditures in industry. (See figure 6-2.) The share of total industrial R&D outlays provided by industry first exceeded funding provided by the Government in 1968, it has continued to increase throughout the 1970's. In constant-dollar terms, the annual rate of increase in company R&D spending was 5.9 percent per year from 1975 to 1985. Preliminary data suggest, however, that the average annual rate of increase from 1985 to 1986 will be only 3.2 percent, and only 2.0 percent from 1986 to 1987. This slowing in the rate of increase is attributed to poor sales expectations, concerns for short-term profitability, and the restructuring of R&D efforts after corporate mergers.[5]

A variety of factors contributed to the recent high rate of private investment in R&D. In 1984, officials from about one-third of a group of large R&D-performing companies reported that the Economic Recovery Tax Act, which included a 25-percent tax credit for incremental R&D expenditures, had favorably influenced their R&D budgets.[6] Moreover, constant-dollar company R&D expenditures did not decrease during the recession in the early 1980's (as they did in the recessions of 1970-71 and 1975). Instead, there was actually an increase, spurred by companies' concern that foreign competition is steadily eroding the U.S. technological lead.[7] A recent study indicates that R&D contributed significantly to industrial productivity in both the 1960's and 1970's, in spite of the overall slowdown in productivity growth and the general worry about the possible exhaustion of technological opportunities. Basic research appeared to make an especially large contribution. Although Federally financed R&D expenditures had a positive effect on productivity, private support contributed significantly more.[8]

### Trends in Federal Funding

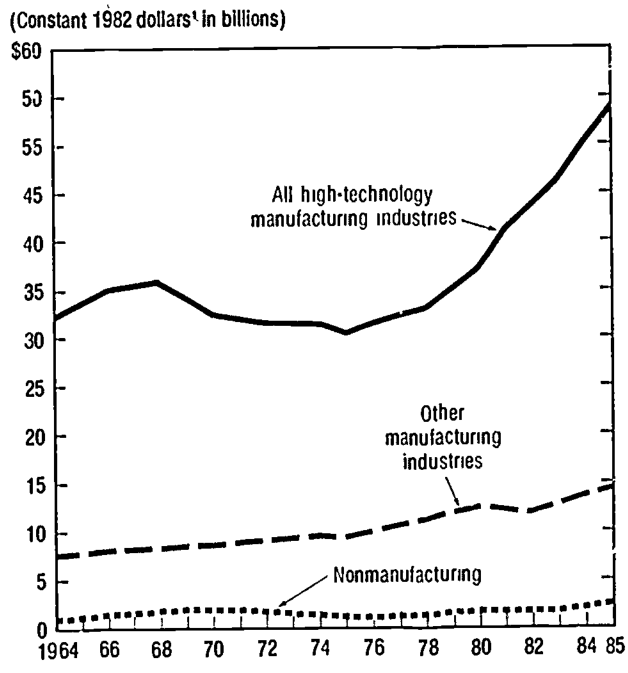
While constant-dollar company funding for R&D has shown an almost uninterrupted increase, Federal funding has shown greater variations. Its historic high was in 1966; after this, cutbacks in many programs (particularly those at NASA) led to a steady overall decline that lasted until 1975. However, Federal constant-dollar expenditures for industrial R&D have increased since 1975 at an estimated 5.6 percent per year through 1987. (Note, however, that the increase from 1986 to 1987 is estimated at only 3.2 percent.) The recent increased emphasis on defense-related R&D has brought the Federal contribution, in constant dollars, back to its 1960's levels. For example, in fiscal year 1987, the Department of Defense (DoD) is contributing an estimated 85 percent of all Federal funding obligations for industrial R&D; in 1980, it only provided 70 percent.

In addition to defense, the Government's policy is to increase support for civilian-oriented basic research, while giving considerably less emphasis to civilian applied research or development. From 1980 to 1987, Federal obligations for industrial basic research —excluding DoD funding—increased by 119 percent, while applied research obligations increased only 13 percent and development obligations decreased by 26 percent. In terms of dollar amounts obligated, development remains by far the largest R&D component: in fiscal year 1987, an estimated 72 percent of all Federal funding obligations for industrial R&D will be for development.

### R&D Expenditures and Employment in Individual Industries

Trends in R&D expenditures vary substantially among industries. For purposes of comparison, industries may be divided into three general groups: high-technology manufacturing, other manufacturing, and nonmanufacturing.[9] (See figures O-29 in Overview and 6-3.) This division is in accordance with current policy interest in high technology, and also reflects the distinction between manufactured goods and services.

Figure 6-3.
**R&D expenditures, by industry group**




[1]GNP implicit price deflator used to convert current dollars to constant 1982 dollars.
Note: Data include Federally Funded Research and Development Centers administered by industry.
See appendix table 6-3. Science & Engineering Indicators — 1987

High-technology manufacturing industries accounted for 76 percent of total R&D funding in 1985. Other manufacturing industries accounted for 20 percent, while

[5]National Science Foundation (1987).

[6]See National Science Foundation (1984).

[7]*Business Week* (1984). This article contains a listing of the companies with the greatest R&D expenditures.

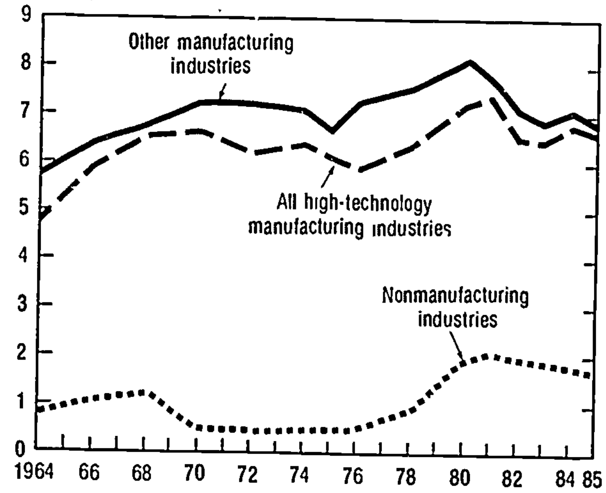
[8]See Griliches (1986).

[9]A list of the industries in each group is shown in appendix table 6-3. High-technology industries are identified in terms of the ratio of their R&D expenditures to their net sales.

nonmanufacturing (including services) accounted for only 4 percent. By comparison, in 1985 only 44 percent of total employment in R&D-performing companies was in high-technology manufacturing, while 45 percent was in other manufacturing, and 12 percent in nonmanufacturing.[10] (See figure 6-4.)

During the 10-year period from 1975 to 1985, the average growth rates of R&D expenditures in the three sectors were 5.9 percent per year in high technology, 4.2 percent in other manufacturing, and 7.5 percent in nonmanufacturing, in constant-dollar terms.[11] During this interval, the growth rate in total employment was 1.1 percent per year in high-technology manufacturing, negative in other manufacturing, but large in R&D-performing nonmanufacturing (7.1 percent per year). This clearly reflects the shift in U.S. industry from goods to services.[12]

Figure 6-4.
**Total employment of R&D-performing companies, by industry**




See appendix table 6-4.

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Between 1980 and 1985—partly a period of economic slowdown—a somewhat different pattern emerged. R&D outlays in high-technology manufacturing increased considerably, rising at a rate of 7.6 percent per year in constant dollars. This was far above the increase in other manufacturing (2.4 percent per year) and the 3.9-percent per year rise in nonmanufacturing. Employment in 1980-85 declined in both high-technology and other manufacturing industries (at rates of 1.4 percent and 3.2 percent per year, respectively) and in nonmanufacturing (1.3 percent per year).

The rapid increase from 1980 to 1985 in high-technology manufacturing R&D was partly due to the aircraft and missiles industry: Federal R&D expenditures in this industry grew at about 56 percent in constant dollars. In dollar terms, Federal support accounted for most of this industry's R&D growth.[13] Another large increase during this period—51 percent, in constant dollars—was in private R&D expenditures in the chemical industry. (See appendix tables 6-5 and 6-6.)

Since 1980, large percentage increases in Federal support have occurred in nonelectric machinery, including computers (83 percent): and in communication equipment (68 percent), which is part of the electric equipment industry. Overall, the R&D support received by different industries from the Federal Government varies widely, ranging from 4 percent for the chemical industry to 76 percent for the aircraft and missiles industry. (See appendix table 6-7.)

## PATENTED INVENTIONS

Industrial R&D produces many benefits for the performing company, among them a stream of new technical inventions that may in turn be embodied in innovations, i.e., in new or improved products, processes, and services. While there is no accepted method for directly counting such inventions, the patents taken out on new inventions can serve as indicators of invention.

Patenting indicators, while instructive and convenient, involve some well-known drawbacks. For instance, many inventions are not patented, yet patented inventions are implicitly taken to represent all inventions with respect to their distributions and rates of increase/decrease. In fact, industries vary considerably in their propensity to patent inventions rather than hold them as trade secrets. For this reason, comparison of patenting rates among different technologies or different industries is inadvisable. Further, counts of patents treat all counted patents as equal, although it is known that patents vary markedly in their technical and economic values. In the absence of an agreed-upon method for rating patents, however, the assumption of their equality is unavoidable. The problem of patent quality is further discussed later in this section.

### Inventors and Owners of Inventions Patented in the United States

The U.S. Patent and Trademark Office issues patents to both U.S. and foreign inventors. The peak year for patents awarded to Americans and for total patents awarded was 1971. (See figure 6-5.) The recent low point was in 1983, but the rise from then to 1986 was a substantial 16

[10]Note that the nonmanufacturing employment figures discussed here do not apply to *all* nonmanufacturing industries, but only to those nonmanufacturing industries that report R&D expenditures.

[11]As noted above, slower increases in total industrial R&D funding are estimated for 198 .

[12]More than one-half of the R&D expenditures and employment in this nonmanufacturing sector are in electric, gas, and sanitary services; computer and data processing services; miscellaneous business services (which include computer programming and other software, and R&D laboratories and commercial testing laboratories); and engineering, architectural, and surveying services The peak year for total employment in R&D-performing nonmanufacturing was 1981.

[13]In 1985, the Federal Government paid for 76 percent of the R&D expenditures in this industry. Aircraft and missiles companies received 51 percent of all Federal R&D support to industry, and accounted for 8 percent of all private support.

percent for U.S. domestic patenting. Foreign patenting in the United States has generally increased between 1970 and 1986, with a 36-percent increase from 1983 to 1986.

These trends are open to various interpretations. If it is assumed that a country's domestic patenting is an indicator of its production of inventions,[14] then the production of inventions in the United States declined in the 1970's. Similar declines were observed in many other industrialized countries, although there were steady increases in Japan. On the other hand, patenting by foreign countries in a large country like the United States may be taken as an indicator of the foreign levels of invention.[15] Under this assumption, the increase of foreign patents in the United States would represent a genuine growth in foreign inventions. Further, the trend in the *number* of patents may not be the same as the trend in the *value* of those patents. For instance, preliminary studies of patenting in West Germany, the United Kingdom, and France show that the economic value of patents applied for in those countries did not drop in the early 1970's, even though the total number of patent applications was declining.[16]

[14]This approach is taken by Schiffel and Kitti (1978) The authors conclude that increasing world trade and the possibilities of exporting to a large and rich market seem to explain the increased foreign filings of patent applications in the United States. The conclusions and method of this study are critiqued by Bosworth (1980) and Basberg (1983).

[15]This approach, along with the preceding one, is discussed by Pavitt (1985).

[16]See Griliches, Pakes, and Hall (1986). These researchers found the distribution of patent values to be very broad and highly skewed. They do not therefore encourage use of patent counts to represent short-run changes in R&D output. They also found that the total value of patent rights is quite high, but still amounts to only 10 or 15 percent of a nation's total expenditure on R&D. Hence, there must be other significant means by which R&D performers seek returns from their investment.

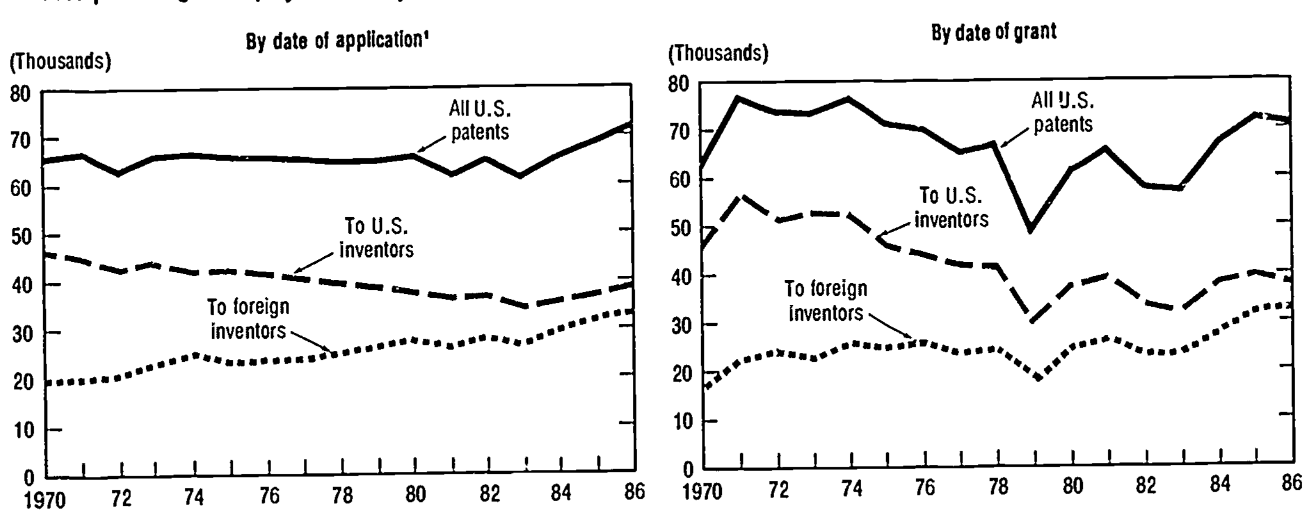
The data in terms of date of patent grant are quite irregular from year to year because of fluctuations in the rate of patent application processing by the Patent Office. To remove these fluctuations, granted patents can be counted in terms of the year in which each patent was applied for. (See figure 6-5.) The application date is roughly 2 or 3 years before the year of grant; it is therefore closer to the time in which the invention actually took place.

In terms of application date.[17] foreign patenting again shows a pattern of fairly steady increase with a few dips in 1975 and the early 1980's. From 1983 to 1986, the increase in foreign patents has been about 8 percent per year. Patenting by Americans shows a much more complicated trend, with a peak in 1969 and a steady decline from 1975 to 1983. From 1983 to 1986, there was a slight recovery at a rate of about 4 percent per year.

The patents received by American inventors can be further analyzed according to their class of owner. (See figure 6-6.) Inventors who work for private companies or for the Government commonly assign ownership of their patents to their employer; self-employed inventors usually retain ownership of their patents. Thus, the owner's sector is a good indication of the sector in which the inventive work was done. In recent years, about 73 percent of U.S. patents have been assigned to corporations. Trends in corporate-owned patents have been very similar to the overall trends in U.S. patenting discussed

[17]Since many of the patent applications filed in recent years have not yet been examined by the Patent Office, it is not known how many of these will ultimately become granted patents An estimate of the expected number of granted patents can be obtained by multiplying the total number of applications for each year by the recent success rate These estimates are used for patenting rates by date of application throughout this chapter.

Figure 6-5.
**U.S. patents granted, by nationality of inventor**




¹Estimates are shown for 1982-86 for patenting by date of application.
See appendix table 6-8.

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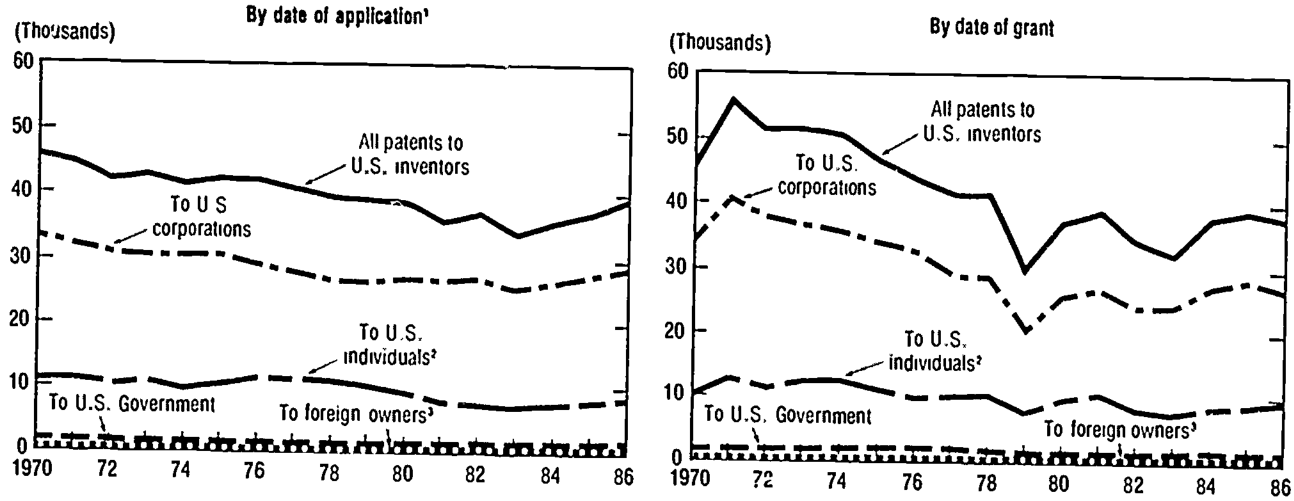
Figure 6-6.
**U.S. patents granted to U.S. inventors, by type of owner**




[1]Estimates are shown for 1982-86 for patenting by date of application
[2]Includes unassigned patents.
[3]Includes foreign corporations, governments, and individuals.
See appendix table 6-9.

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above. In all three sectors, the patenting rate was at its most recent peak in the mid-1970's, and has been relatively flat since 1980.

Data on patenting by corporations include information on several kinds of small entities—i.e., universities, individuals, and small companies—whose patenting patterns are of interest in their own right. For example, about 1.4 percent of patents granted to Americans are currently assigned to universities. (See chapter 5, "Academic R&D and Basic Research: Patterns of Performance," for a discussion of the technical fields in which this patenting is concentrated.) Such patenting is encouraged by the Uniform Federal Patent Policy Act of 1980 (amended 1984), which permits nonprofit organizations and small businesses to retain patent rights for inventions achieved with Federal grant money. In 1986, 636 patents were granted to U.S. universities and colleges. While this represents an increase over earlier years (in 1976, U.S. universities were assigned only 345 patents), it does not reflect all of the inventive activity that takes place at universities. Although university staff and faculty may assign their patent rights to their institution, they also may sometimes retain the rights as individuals or assign them to small companies with which they are associated.[18] Thus, a fuller picture of academic patenting trends is obtained by considering patenting by individuals and small companies. (See table 6-1.) Individuals, some of whom have a university affiliation, own about 20 percent of all U.S. patents. In addition, small business entities have substantial rates of patenting: about 12 percent of patents awarded in 1986 were owned by small companies.[19] Some of this patenting should also be credited to academic researchers.

The patents granted to foreign inventors can be assessed by country. (See figure 6-7 which shows the four largest foreign patenting countries.) Since 1975, Japan has been the largest foreign patenting country in terms of date of grant. Japanese inventors received 19 percent of all patents granted by the U.S. Patent and Trademark Office in 1986. The next largest foreign patenting nation

[18]Staff or faculty members may also license their patents to small or large companies, but licensing transactions are not reflected in the present data.

[19]These small business patents are identifiable because small entities are permitted to file for a partial rebate of the patent application fee. However, some of the patents for which the lower fee was paid were assigned to individual owners or were unassigned. If one counts only corporate owners, 10.0 percent of the patents granted in 1985, and 9.5 percent of those granted in 1986, were owned by small companies.

**Table 6-1. Percent of U.S. patents granted to U.S. small entities**

| Year | Small business | Individuals | Colleges and universities |
|---|---|---|---|
| | | Percent | |
| 1983 ....... | NA | 23.0 | 1.3 |
| 1984 ....... | NA | 23.2 | 1.4 |
| 1985 ....... | 12.6 | 23.4 | 1.4 |
| 1986 ....... | 11.7 | 24.8 | 1.7 |

SOURCES: U.S. Patent and Trademark Office, *TAF Report: All Technologies Report* (April, 1986), *TAF Report: All Universities* (June, 1987), and unpublished data

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1 : 9

was West Germany, with 10 percent. Since 1980, Japanese patenting in the United States has increased 85 percent, the increases for West Germany (18 percent), the UK (0 percent), and France (13 percent) were much less.

In terms of patent applications, the results are similar. Japanese inventors in 1986 submitted 19 percent of all applications received by the U.S. Patent Office. American inventors submitted 53 percent. Since 1980, Japanese patent applications have increased by 77 percent, while West German applications have increased by 10 percent, British applications by 11 percent, and French applications by 17 percent. In contrast, American applications to the U.S. Patent Office increased by 5 percent from 1980 to 1986.[20]

### Patenting by Individual Countries in Various Technical Fields

The decline in patenting by Americans from the mid-1970's to 1983 occurred in many important technical areas,[21] and may presage a shift in the economic condition of the corresponding industries. From 1975 to 1986, the share of U.S. patents granted to Americans dropped from 65 percent to 54 percent. (See appendix table 6-10.) Nearly all of this drop is due to the increase of Japanese-origin patents. The U.S. share dropped most in the following areas: aircraft and parts,[22] motor vehicles and other transportation equipment, and office, computing, and accounting machines (including computers). These are all fields in which Japanese patenting increased markedly. West German inventors increased their share of patenting in nonelectrical machinery. In general, the other countries have low shares of the patents in all fields, these shares did not change substantially.

The technology areas discussed above are very broad, and do not include some specific technologies of current interest. To study such technologies, patents were combined into special technology fields.[23] Unfortunately, this was not practical for some important fields, like biotechnology, but 15 fields of interest were developed. (See appendix table 6-11.)

U.S. patenting, in terms of counts of patents, increased from 1975 to 1986 in 6 of the 15 fields and decreased in the others. The share of patents going to Americans decreased in every field except genetic engineering. Although this is a narrowly defined field and contains few patents, the U.S. share here rose considerably, increasing from 27 to 78 percent. On the other hand, the U.S. share of patents in internal combustion engines dropped from 54 to 28 percent.

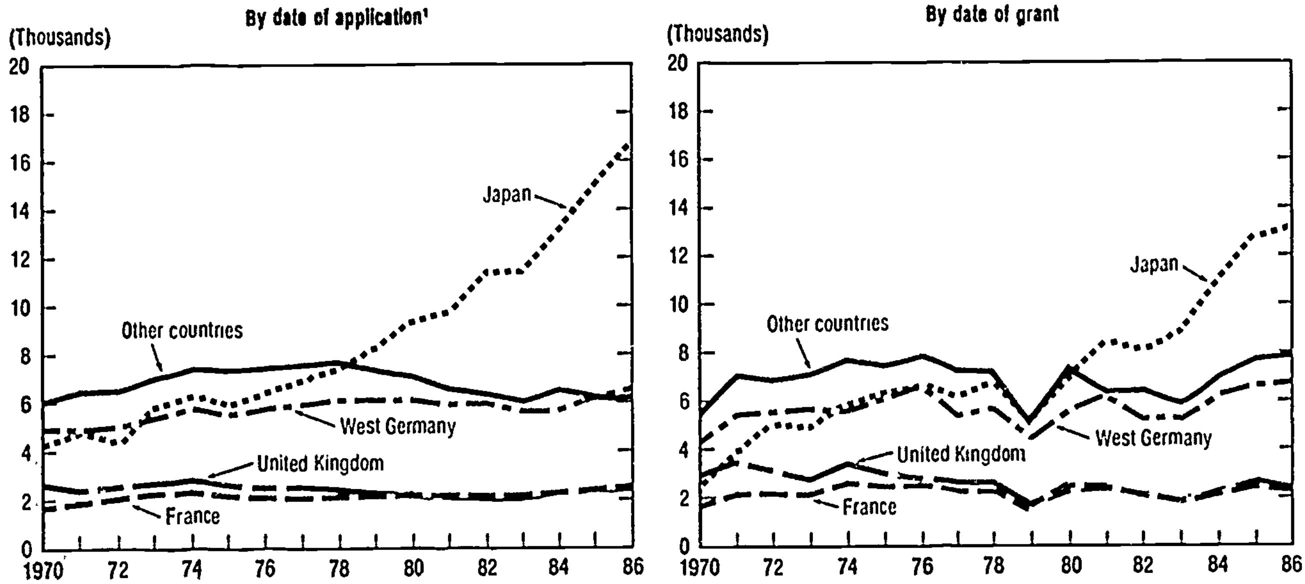
[20] Data from the U.S. Patent and Trademark Office, special tabulations.

[21] Patenting in these technical areas was estimated by means of the "Concordance," a computer program maintained by the U.S. Patent and Trademark Office that converts patent counts from the Patent Office classification system into patent counts in terms of Standard Industrial Classification (SIC).

[22] The large Japanese increase in this field, along with motor vehicles and other transportation, suggests the possibility that some automotive patents are illegitimately being counted as aircraft patents. See U.S. Patent and Trademark Office (1985), pp. 80-81.

[23] In this case, the Concordance was not used, but Patent Office subclasses were directly combined to make up the technologies of interest.

Figure 6-7
**U.S. patents granted to foreign inventors, by nationality of inventor**




[1] Estimates are shown for 1982-86 for patenting by date of application.
See appendix table 6-8.

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The Japanese share of patents increased in every technology except genetic engineering, and especially in internal combustion engines (from 17 percent to 44 percent) and in laser light sources and detectors (from 14 percent to 35 percent). Increased West German participation is seen in light wave technology and in robots, although the total number of patents involved is small, increased French activity is found in nuclear energy.

### Citations from Patents to Previous Patents

One of the main problems in using patent counts as indicators of the volume of technical invention is that not all patents are equally significant. Of the several promising approaches to this problem that have been suggested, one involves the use of interpatent citations.

The front page of a patent document generally contains a list of previous patents that serve as "prior art," i.e., previous significant achievements in the same field of invention that must be taken into account in judging the novelty and significance of the present invention. Such lists of citations therefore indicate which are the most significant patents in a given field. patents receiving many citations from later patents are presumably more technically important than those receiving few citations.[3]

U.S. patent citation data suggest that Japanese patents are not only increasingly numerous in the U.S., but that they are also of especially high quality. (See table 6-2.) The patents taken out by American inventors in 1975 had received an average of 3.05 citations each by the end of 1986. This was surpassed only by the Japanese patents, which received 3.30 citations on average in the same period. All other countries shown received a lower number of citations. These numbers reflect citations from U.S. Patent and Trademark Office examiners who evaluate patent applications in terms of their significance and novelty. These patent examiners accorded somewhat more importance to patents granted to Japanese applicants in 1975 than to those granted to Americans. If one assumes that American patent examiners would tend to prefer citing American patents, then their emphasis on Japanese patents becomes all the more striking.

Patents owned by U.S. corporations and by foreign entities were more often cited by American applicants than were patents owned by the U.S. Government or by individual Americans. Overall, the patents granted to Japanese inventors in 1975 were cited about as often as those granted to U.S. corporations—about 3.3 times each—on average. Since it is likely that the Japanese patents are mostly corporate-owned, it appears that those U.S. and Japanese corporate-owned patents taken out in the U.S. are of about the same quality. This argument does not explain, however, why the patents from nationals of other countries are less frequently cited.

It would be helpful to have the rates of citation to more recent patents. Unfortunately, since it takes many years for a patent to receive all its citations, patents granted in recent years have only a small fraction of the citations they will eventually have. For patents granted in 1983, the data on these incomplete citations show that the relative quality of Japanese patents was even higher than in 1975. (See table 6-2.) Patents with U.S. inventors are again more frequently cited than those coming from the other eight countries, but patents with Japanese inventors are cited even more than patents with U.S. inventors owned by U.S. corporations.

The success rate of applications to the U.S. Patent Office provides supplementary information on the quality of patents from different countries. (See appendix table 6-12.) Because of the importance of the United States as a market, significant inventions in various countries are commonly patented here as well as in their home country if there is any chance that they can be exploited in the U.S. through trade or licensing. Of the patent applica-

[3]A study of technologically important patents showed that they received twice as many of these examiners' citations as does the average patent. See Carpenter, Narin, and Woolf (1981).

**Table 6-2. Citations from U.S. patents to earlier U.S. patents, by country of inventor or sector of owner of cited patents**

| Year of cited patents | United States | Japan | Netherlands | United Kingdom | West Germany | Canada | Sweden | France | Switzerland | Italy |
|---|---|---|---|---|---|---|---|---|---|---|
| | Country of inventor | | | | | | | | | |
| | Citations per citable patent | | | | | | | | | |
| 1975 | 3.05 | 3.30 | 2.93 | 2.87 | 2.65 | 2.57 | 2.46 | 2.43 | 2.42 | 2.41 |
| 1983[1] | 0.68 | 0.92 | 0.62 | 0.59 | 0.59 | 0.53 | 0.51 | 0.58 | 0.57 | 0.49 |

| Year of cited patents | All U.S. inventors | Sector of owner, for U.S. inventors: U.S. corporations | U.S. government | U.S. individuals | Foreign owners |
|---|---|---|---|---|---|
| | Citations per citable patent | | | | |
| 1975 | 3.05 | 3.27 | 2.28 | 2.53 | 3.32 |
| 1983[1] | 0.68 | 0.75 | 0.48 | 0.47 | 0.80 |

[1] These numbers are expected to increase as more citations are made to 1983 patents in later years.

SOURCE: Computer Horizons, Inc., unpublished tabulations provided to the National Science Foundation

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tions filed in the U.S. by nationals of different countries in 1975 and 1981,[27] Japanese applicants have been particularly successful (French applicants in 1975 also had a high success rate). These data, of course, are subject to various interpretations. For example, the low success rate for British and Canadian applicants may be due to the common use of English, which makes it easier for them to file applications in the U.S., and thereby may lower the average quality of the filings. Conceivably, Japanese filings are of especially high quality for a similar reason, but in any case the data do not support the supposition that the large number of Japanese filings is associated with a lower average quality. Several foreign countries have higher success rates than do American applicants. this supports the idea that foreign countries file their most important inventions in the United States, rather than a uniform selection of their inventions of all qualities.[28]

## SMALL BUSINESS IN HIGH TECHNOLOGY

The role of small businesses within the science and technology system is ambiguous and controversial. On the one hand, they are believed to be disproportionately innovative; to be less tied to existing products and processes than are large, well-established firms; and/or to offer better incentives to their S/E workers, who are more likely to hold substantial ownership interests in their work. Small businesses may also be better able to exploit small market niches that are ignored by larger firms. On the other hand, they are seen as generally lacking the financial, production, and marketing resources of larger firms; they may also be unable to reduce their exposure to risk through diversification. Furthermore, if a small firm does succeed in identifying and developing a successful innovation, it typically must be able to expand its production and marketing efforts rapidly in order to profit from its innovation.

Regardless of whether small businesses are more or less innovative than larger firms, their ability to prosper is probably a major element in keeping the American economy competitive, and in maintaining its ability to develop, adopt, and diffuse new technologies. The creation and growth of small compan[illegible] based on innovations—particularly those marketing new products—provide an alternative channel for introducing new technologies. While large enterprises, with their R&D programs and established technical and marketing expertise, will certainly continue to provide a major share of the Nation's inventions and innovations, there will be circumstances wherein the established firm will not be an effective vehicle for introducing new technologies The small business alternative is therefore of great interest, although it is not always the superior vehicle for innovation.

No instruments exist for directly measuring the relative effectiveness of small business as an agent for technological change. This section therefore concentrates on measures of the viability of small firms, particularly in high-technology industries. It covers indicators of small business activity in high-technology indus[illegible]y overall, as well as detailed information on the financial environment for small high-technology enterprise, and information about small business in biotechnology, an important high-technology area.

This discussion generally follows the Small Business Administration (SBA) rule of describing firms with less than 500 employees as small businesses, and those with 500 or more employees as medium or large.[29] Definition of high-technology firms is more difficult. For this analysis certain products or industries first are identified as high-technology, then firms producing such goods or belonging to such industries are classified as high-technology firms The primary division of industries into high-technology and non-high-technology industries is the [illegible]-3 classification, based on direct and indirect R&D expenditures attributed to a product as a percent of net sales.[30]

### Employment in Small High-Technology Enterprises

Employment is a useful indicator of the level of activity within a sector of the economy. In 1984, small firms in high-technology manufacturing industries employed more than 710,000 people, up from about 590,000 in 1980. In three technology-related service industries (computer and data processing services; engineering, architectural, and surveying services; and noncommercial educational, scientific, and research organizations), another 682,000 were employed in small firms in 1984, compared to 542,000 in 1980. Small firms accounted for about one-quarter of employment in the high-technology manufacturing and technology-related service industries. (See table 6-3.) This is a substantially lower share of employment than is accounted for by small businesses in the U.S. economy as a whole. In 1984, small firms accounted for 56 percent of all manufacturing industry employment in the United States,[31] and about 80 percent of employment in the private sector as a whole. (See appendix table 6-13.)

These employment data may understate the role of small business in high-technology industry. First, it is not surprising that "small business" accounts for a much larger share of employment in the rest of the economy than in the high-technology sector. The service industries in particular are dominated by very small businesses (e.g., service stations, restaurants, haircutters, etc.). Second, the identification of high-technology industries is based on reported R&D expenditures. Small businesses

[27]This (1981) is the last year for which a substantial share of applications have been processed, as of the end of 1986.

[28]The patent citation data discussed above gave some support to this interpretation, but only in the case of Japan.

[29]The definition of small businesses using a size cutoff, based either on employment or sales, clearly involves an arbitrary choice. The selection of a different cutoff would certainly alter the trends and levels reported here. In this discussion the data are available according to specified cutoffs, which are reasonable—if imperfect—indicators of small business status.

[30]Indirect R&D expenditures are the share of R&D expenditures by industries supplying the industry which are attributed to the industry, using an input-output table. See U.S Department of Commerce, International Trade Administration (1983), pp. 33-37. See also the discussion on p. 133 of chapter 7, "The International Markets for U S Technology"

[31]See U.S. Department of Commerce, Bureau of the Census (1986), p. 507.

**Table 6-3. Employment in high-technology industries, by size of firm and industry**

| Industries | Small firms[1] 1980 | Small firms[1] 1984 | Large firms 1980 | Large firms 1984 | Small firms' share of total employment 1980 | Small firms' share of total employment 1984 | Distribution of employment by small high-technology firms 1980 | Distribution of employment by small high-technology firms 1984 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Percent | | | |
| High-technology manufacturing industries[2] | 591,332 | 710,421 | 2,930,019 | 3,195,418 | 16.8 | 18.2 | 52.2 | 51.0 |
| Guided missiles & spacecraft | 991 | 1,485 | 88,839 | 100,388 | 1.1 | 1.5 | 0.1 | 0.1 |
| Communications equipment & electronic components | 265,358 | 317,882 | 965,324 | 1,108,090 | 21.6 | 22.3 | 23.4 | 22.8 |
| Aircraft & parts | 44,558 | 47,147 | 507,756 | 498,352 | 8.1 | 8.6 | 3.9 | 3.4 |
| Office, computing & accounting machines | 49,898 | 86,888 | 347,548 | 472,815 | 12.6 | 15.5 | 4.4 | 6.2 |
| Drugs & medicines | 31,154 | 35,228 | 196,762 | 181,299 | 13.7 | 16.3 | 2.7 | 2.5 |
| Industrial inorganic chemicals | 7,074 | 5,437 | 54,382 | 53,138 | 11.5 | 9.3 | 0.6 | 0.4 |
| Professional & scientific instruments | 160,134 | 184,079 | 380,934 | 440 763 | 29.6 | 29.5 | 14.1 | 13.2 |
| Engines & turbines | 6,066 | 6,813 | 172,659 | 158,304 | 3.4 | 4.1 | 0.5 | 0.5 |
| Plastic materials & synthetics | 26,099 | 25,462 | 215,815 | 182,269 | 10.8 | 12.3 | 2.3 | 1.8 |
| Technology-related service industries[3] | 542,032 | 682,055 | 542,755 | 589,622 | 50.0 | 53.6 | 47.8 | 49.0 |
| Computer & data processing services | 150,019 | 242,643 | 156,037 | 241,646 | 49.0 | 50.1 | 13.2 | 17.4 |
| Engineering, architectural & surveying services | 357,529 | 403,944 | 264,174 | 288,799 | 57.5 | 58.3 | 31.5 | 29.0 |
| Noncommercial educational, scientific, and research organizations | 34,484 | 35,468 | 122,544 | 59,177 | 22.0 | 37.5 | 3.0 | 2.5 |
| All technology-related industries | 1,133,364 | 1,392,476 | 3,472,774 | 3,785,040 | 24.6 | 26.9 | 100.0 | 100.0 |

[1] Firms with less than 500 employees.

[2] Industries whose products meet the DOC 3 criteria for high-technology products. See U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (February, 1983), pp 33-37.

[3] Service industries identified by the Small Business Administration as high technology, but excluding Business Services, N.E.C and Service Industries, N.E.C.

SOURCE: U.S. Small Business Administration, Office of Advocacy, special tabulations

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are less likely to have separately budgeted R&D expenditures, or distinct R&D departments, than are larger firms. The industries reporting high R&D expenditures may therefore be those dominated by large firms. Third, the successful small high-technology firm will generally grow larger either through internal growth or through merger[40] with other firms in order to exploit its innovations.

One measure of the success of high-technology enterprise might be the growth of employment in those industries relative to the rest of the economy.[41] Employment in the technology-related industries was 12 percent higher in 1984 than in 1980, while total private sector employment grew by about 4 percent. (See table 6-3 and appendix table 6-13.) Employment in small firms in the technology-related industries grew by about 20 percent during this period, while employment in all small businesses grew by 6 percent.

The vitality of the small high-technology business sector is even more striking when it is considered that some of the firms counted as small, high-technology enterprises in 1980 had, by 1984, become large firms. Thus, 581 firms—which in 1980 accounted for almost 10 percent of employment in small business high-technology manufacturing establishments—were no longer counted as small businesses in 1984, either because of internal growth or because merger and acquisition activity had made them parts of larger enterprises. (See table 6-4.)

The tendency for small businesses to become large ones varies considerably among industries. For example, relatively few small firms in the technology-related service industries grow or merge into large firms. This is not surprising, as large firms are relatively unimportant in these industries, accounting for about 46 percent of their employment in 1984, as compared—on the other hand—

[40] "Merger" is defined here to include all cases where the firm is joined with another firm, whether the transaction involves the purchase of one firm by another or exchanges of stock and other poolings of ownership

[41] It should be noted, however, that a successful process innovation may involve a simultaneous increase in sales and reduction in employment, if the associated increase in labor productivity is sufficient

with 82 percent in high-technology manufacturing industries. (See table 6-3.) In some high-technology manufacturing industries, there is a fairly strong tendency for small businesses to gain large status. Firms accounting for 16.0 percent of 1980 small business employment in the office, computing, and accounting machine industry were part of large firms in 1984, as were industrial inorganic chemicals firms (14.5 percent of 1980 employment), and firms in communications equipment and electronic components and in drugs and medicines (more than 10 percent of 1980 employment in each). (See table 6-4.)

Of these four industries, only in one—communications equipment and electronic components—was small business relatively important, accounting for about 20 percent of employment in both 1980 and 1984. In the other industries with fairly strong tendencies for small firms to grow larger, small business accounted for less than 15 percent of industry employment in 1980. It is entirely possible, therefore, that the shift of these firms from small status to large was in response to factors that make a large-size firm optimal for those industries, rather than being a demonstration of small businesses' flexibility and technological dynamism. On the other hand,

**Table 6-4. Employment of small business,[1] high-technology establishments that in 1984 were non-small-business, high-technology establishments, by industry: 1980, 1984**

| Industries | 1980 Small business (SB), high-technology (HT) establishments | | 1984 non-small-business, high-technology establishments which were small-business, high-technology in 1980 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1980 | 1980 | | 1984[2] | | 1980 share of all 1980 SB, HT establishments | |
| | Number | Employment | Number | Employment | Number | Employment | Number | Employment |
| | | | | | | | Percent | |
| High-technology manufacturing industries[3] | 23,774 | 591,332 | 581 | 52,797 | 581 | 88,548 | 2.4 | 8.9 |
| Guided missiles & spacecraft | 28 | 991 | 1 | 30 | 1 | 50 | 3.6 | 3.0 |
| Communications equipment & electronic components | 9,934 | 265,358 | 261 | 27,508 | 261 | 45,491 | 2.6 | 10.4 |
| Aircraft & parts | 1,282 | 44,558 | 21 | 2,064 | 21 | 2,592 | 1.6 | 4.6 |
| Office, computing & accounting machines | 1,667 | 49,898 | 101 | 7,986 | 101 | 16,340 | 6.1 | 16.0 |
| Drugs & medicines | 1,359 | 31,154 | 38 | 3,716 | 38 | 5,025 | 2.8 | 11.9 |
| Industrial inorganic chemicals | 332 | 7,074 | 24 | 1,027 | 24 | 1,102 | 7.2 | 14.5 |
| Professional & scientific instruments | 7,880 | 160,134 | 101 | 9,281 | 101 | 13,924 | 1.3 | 5.8 |
| Engines & turbines | 290 | 6,066 | 2 | 54 | 2 | 39 | 0.7 | 0.9 |
| Plastic materials & synthetics | 1,002 | 26,099 | 32 | 1,131 | 32 | 3,985 | 3.2 | 4.3 |
| Technology-related service industries[4] | 45,426 | 542,032 | 533 | 27,846 | 533 | 40,866 | 1.2 | 5.1 |
| Computer & data processing services | 12,268 | 150,019 | 294 | 13,059 | 294 | 21,442 | 2.4 | 8.7 |
| Engineering, architectural & surveying services | 31,526 | 357,529 | 227 | 14,200 | 227 | 18,690 | 0.7 | 4.0 |
| Noncommercial educational, scientific, and research organizations | 1,632 | 34,484 | 12 | 587 | 12 | 734 | 0.7 | 1.7 |
| All technology-related industries | 69,200 | 1,133,364 | 1,114 | 80,643 | 1,114 | 129,414 | 1.6 | 7.1 |

[1] Firms with less than 500 employees.

[2] Broken down by 1980 industry

[3] Industries whose products meet the DOC-3 criteria for high-technology products. See U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (February, 1983), pp 33-37.

[4] Service industries classified by the Small Business Administration as high technology, but excluding "Business Services, N.E.C" and "Service Industries, N.E.C"

SOURCE: U.S. Small Business Administration, Office of Advocacy, special tabulations

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the share of employment accounted for by small firms increased between 1980 and 1984 from 12.6 percent to 15.5 percent in the office, computing, and accounting machine industry; and from 13.7 to 16.3 percent in the drugs and medicines industry. In these industries, small businesses seem to be increasingly viable. Furthermore, since relatively large numbers of small firms in these industries grow to medium- or large-firm status, the growth of such small firms seems to follow technological or other commercial success.

### Venture Capital and High-Technology Enterprise

The growth of small businesses and the introduction of new products require access to pools of capital. Compared to larger firms, small businesses—particularly new firms that seek to develop and exploit a new technology—are handicapped by both the lack of a financial track record and a narrow scope of business activities. These factors combine to make it difficult for a firm to secure traditional financial support, i.e., obtaining bank loans or selling equity in the stock markets. In the United States, the need for financing for small, innovative firms has been at least partially met by a variety of funding mechanisms not generally available outside the U.S. These include an active venture capital industry (described below), small-firm equity markets—such as the NASDAQ listings and markets made by individual stock brokerages—and other financing systems, such as personal funds, funds from wealthy families and individuals, and trust funds.

Venture capitalists invest in small, young, rapidly growing companies that may not have access to public or credit-oriented institutional funding. Their investments may be divided into three classes, two of which are of primary concern here.[32] First, early-stage investments support the entrepreneur or inventor up through initial commercial manufacturing and sales. Later-stage financing supports firms that are producing and shipping, but are as yet unable to finance substantial expansions and investments in plant. Later-stage financing is typically geared toward the sale of stock to the public, known as the Initial Public Offering (IPO). Most venture capital investments are equity-related, either through direct purchase of stock or through options and other equity-related arrangements. These investments usually emphasize long-term (5 to 10 years) opportunities, and closely involve the investors with the operations of the capital recipient, frequently through participation on the board of directors.

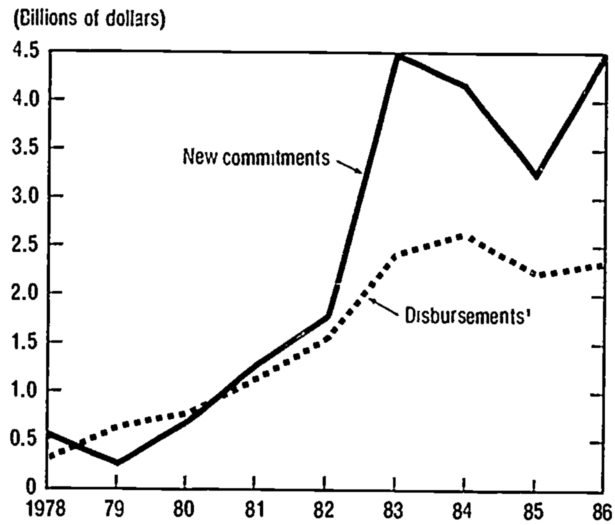
In 1985, the pool of capital managed by venture capital firms was $24.1 billion, 6.9 times as great as it was in 1978. (See appendix table 6-14.) During this period when venture capital emerged as a strong source of finance for small, innovative firms, new funds made available to venture capitalists grew from $600 million in 1978 to $4.5 billion in 1986. The venture capitalists in turn increased their investments (excluding debt lending and financing for leveraged buyouts) from about $300 million in 1978 to some $2.7 billion in 1984, and to $2.4 billion in 1986. (See figure 6-8.)

During the last 3 years studied, new capital commitments have exceeded disbursements by the venture capital industry, even when debt financing and leveraged buyout financing are taken into account. There is thus apparently a surplus of venture funds seeking outlets in new or expanding innovative firms. This surplus could dry up as quickly as it appeared: the venture capital industry is highly sensitive to the business cycle and to changes in tax laws, particularly with respect to the treatment of long-term capital gains.

In 1986, early- and later-stage investments combined accounted for about 93 percent of all venture capital disbursements. (See appendix tables 6-14 and 6-15.) The industry producing computers and computer-related products and services received the largest share of both early- and later-stage investments: this industry received $254 million in early-stage financing and $429 million in later-stage financing in 1986. Other industries receiving substantial venture capital investments were the communications industries, and those producing electronic components and other electronic products (including instruments).

Biotechnology (including recombinant DNA, monoclonal antibodies and hybridomas, and other genetic engineering) has received smaller, but increasing, amounts of venture capital during the years for which data are available. In 1984, this industry received about $63 million in early- and later-stage investments; in 1986, it received $117 million. Interestingly, biotechnology venture capital was more concentrated in later-stage investment than for any other industry except industrial equip-

Figure 6-8.
**Venture capital commitments and disbursements**




¹Excluding SBIC straight debt lending and leveraged buyout financing.
See appendix table 6-14.

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[32]Definitions and discussion are based on Venture Economics, Inc. (1985).

ment, which was an insignificant recipient of venture capital. Either the biotechnology industry is experiencing a lower rate of new-firm introduction than are some of the other— presumably better established—industries (e.g., computers, communications, and electronic components), or there are other sources of funds for new entrants that are at present more important than venture capital, e.g., investments by large pharmaceutical concerns. (See appendix table 6-15.)

Initial Public Offerings are another indicator of the financial development of new firms. At this stage, a firm is presumably well enough established—either through access to superior technology or through actual production and sales capability—that it can raise money through the stock market. The computer and computer-related industry received the bulk of investment reported, although its share was falling: about 54 percent of all venture-backed IPO's by small businesses in 1984, and 26 percent of such IPO's in 1986. IPO's were more heavily oriented toward non-high-technology industries (particularly consumer goods, but also industrial equipment and machinery) than were direct venture capital investments, presumably reflecting the greater certainty associated with new firms in industries with well-established technologies and product lines. In 1986, there was a surge of venture-backed IPO's in biotechnology firms, with almost $270 million (or 18 percent of the total capital) raised in this fashion. (See appendix table 6-16.)

### Small Business and Biotechnology

The biotechnology industry is particularly important to a study of business—especially small business—in the science and technology system. First, it is an industry that has a large science component, using techniques such as recombinant DNA and hybridomas that are the continuing subject of intensive work in university and private basic research laboratories. Second, the biotechnology industry is one whose leaders have emerged from the ranks of small business. Genentech, for example, was formed in 1976, made its IPO in 1980, and by 1984 still employed only 560; Cetus was formed in 1971, made its IPO in 1981, and employed 600 in 1985.[33]

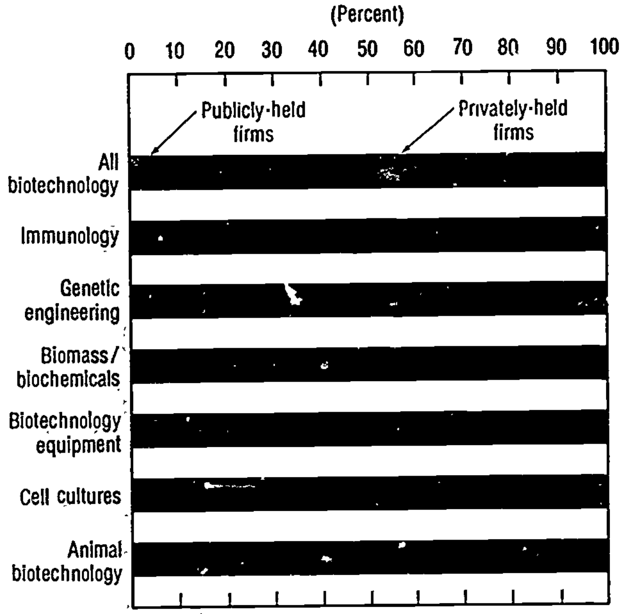
To examine more closely small business' role in the biotechnology industry, a commercial data base containing a large number of firms active in high-technology industries was searched. The data base attempts to be all-inclusive; when prospective firms are identified, questionnaires are sent covering their size, status (private or public, independent, subsidiary, or joint venture), year formed, and product groups in which they are active. The version of the data base used here includes more than 12,000 firms. Of these, 380 reported activity—i.e., either production, sales, or R&D activity—in the fields defined by the data base as biotechnology.[34]

There were 252 independent firms with fewer than 1,000 employees active in biotechnology in the data base. There were also 7 independent firms with more than 1,000 employees, and 120 firms that were either joint ventures or subsidiaries of larger firms, of which 95 reported fewer than 1,000 employees. Although some of the latter firms probably can also be characterized as small businesses, it is not practical to separate them from the small subsidiaries of medium and large businesses. Discussion here therefore concentrates on the 252 small independent firms.

More than one-half of these firms were active in either genetic engineering or biotechnology equipment. About one-sixth of the firms were active in cell cultures, while many were also active in animal biotechnology, immunology, and biomass/biochemicals. (See appendix table 6-17.) There was relatively little cross-technology activity, except between genetic engineering and immunology, where 11 firms—almost one-sixth of those firms reporting activity in genetic engineering, and more than one-third of the immunology firms—were active in both. Perhaps surprisingly, the firms active in biotechnology equipment were not highly involved in other technologies.

About one-quarter of the 252 firms were publicly held. There is, however, some variation in this: close to 40 percent of the firms active in immunology were public, as were about 30 percent of the firms in genetic engineering. (See figure 6-9.) These technologies are at the heart of the biotechnology revolution, encompassing the testing and

Figure 6-9.
**Small[1] firms active in biotechnology, by status of firms: 1986**




[1]Firms with fewer than 1,000 employees.
See appendix table 6-18. Science & Engineering Indicators — 1987

[33]See Dibner (1986), table 5.1.
[34]The data base used is the CorpTech data base, provided by Corporate Technology Information Services, Inc., Wellesley Hills, MA. See appendix table 6-17 for a list of the biotechnology classes used.

diagnostics market and the recombinant DNA technique. The other technologies described here may be more specialized areas that one might expect to develop during later stages of the industry's growth.

The data base reports firm age, based on year of firm founding. The number of small biotechnology firms founded annually increased steadily through the late 1970's, reaching a peak of 40 firms in 1980. New firm formation remained at a high level during 1982 and 1983. It is not clear whether the smaller number of firms in the data base that were formed during 1984 and 1985 indicates a decrease in the actual formation of new biotechnology firms, or if it reflects the time for a firm to be included in the data base. Examining the age of firms in individual technologies, the rate of new firm formation in immunology fell sharply after 1981, when almost one-third of the firms active in immunology were formed. The number of new firms in genetic engineering has also decreased sharply since 1981 and 1982. In contrast, cell cultures and animal biotechnology seem to be the subject of more recent attention. A large number of firms active in biotechnology equipment were formed prior to the biotechnology revolution—29 of the 67 equipment firms were formed prior to 1975. This presumably reflects a migration of established instrumentation and fermentation firms into the new industry. There has also been, however, a substantial increase recently in the number of new firms active in the equipment industry; this perhaps reflects the development of new processes and equipment in the pursuit of new products. (See appendix table 6-19.)

Combining the information about the traded status of small firms with that about the firms' ages suggests that the biotechnology revolution has in fact reached a stage of consolidation, as new firms increasingly move into specialized niches (such as animal biotechnology, cell cultures, and equipment), leaving the core areas of immunology and genetic engineering to those firms who established early leading positions.

As the data base matures, it should be possible to follow in greater detail the evolution of this exciting industry, and to extend its use to other new areas. In the meantime, analysis of the biotechnology industry should be considered as preliminary.

## TECHNOLOGICAL INNOVATION IN INDUSTRY

The indicators so far considered in this chapter have described the resources devoted to innovation (e.g., science and engineering employment), or intermediate products (e.g., patented inventions). None of these is a valid measure of the output of technological innovation produced by these efforts. Such a measure would be especially useful to have in view of the current policy interest in maintaining and improving U.S. industrial competitiveness through the creation and implementation of new technology. Innovation as such is unfortunately difficult to measure, but the results of some limited studies are presented in the following paragraphs.

### Innovation and Innovative Efforts Across U.S. Industry

One survey of 620 manufacturing companies[35] permits an estimate of the output of new products first marketed in 1985.[36] (See figure O-30 in Overview.) In terms of company size, the smallest companies clearly produced the greatest number of new products per million dollars of R&D; this is also true of the number of products per million dollars of net sales. (See appendix table 6-20.) In addition, the number of products per R&D or sales dollar decreases uniformly as company size increases. This shows that small companies are especially dependent on the sale of new products.

R&D expenditures accounted for about 40 percent of the average costs associated with the products first introduced in 1985. The remaining costs were equally split among plant and equipment, production and startup, and marketing and advertising.[37] These proportions were about the same for companies of different sizes. The proportion of new product costs attributed to R&D ranged from 50 percent in the electrical equipment industry to 26 percent in the food industry.

The responding firms reported that new products first marketed in the 1981-85 period accounted, on average, for 25 percent of 1985 sales.[38] In terms of individual industries, instrument firms and electrical equipment firms reported, on average, that more than 40 percent of their 1985 sales were due to such new products, as compared with slightly more than 10 percent for printing companies and food companies. Companies with sales of $200 million or less reported a greater proportion of sales attributable to new products (about 30 percent) than did larger companies (about 20 percent).

The responding firms were divided into three groups according to their size and industry. A group of large R&D-intensive companies was identified, where each company had at least $1 billion in gross annual sales in 1985 and belonged to an R&D-intensive industry.[39] A second group belonged to the same R&D-intensive industries, but had gross annual sales between $35 million and $1 billion. A third group included companies in both size ranges but in the remaining, non-R&D-intensive manufacturing industries.

An important strategy for developing new technology is the award of research grants or contracts to univer-

[35]Hansen, et al. (1987).

[36]A new product is defined as one—newly produced by the responding firm—whose features, performance, or cost is substantially different from its earlier products. Thus the product may in fact have been produced earlier by another company.

[37]The choices offered were. (1) research and development, (2) purchase, installation, and renovation of plant and equipment, (3) production startup, including trial production runs; and (4) marketing, sales, and advertising for new product introduction.

[38]Note that this is a different group of new products from that discussed in the preceding paragraph.

[39]These industries were defined as those with an R&D/net sales ratio of at least 1 percent, in addition to those that annually spend at least $1 billion on R&D.

sities.[10] Nearly 80 percent of the large R&D-intensive companies made such awards during 1985, as opposed to about 30 percent of the smaller R&D-intensive firms and less than 25 percent of the non-R&D-intensive firms. The granting of such awards was directly related to company size, with 100 percent of firms with gross sales more than $4 billion and less than 15 percent of those with sales below $65 million making R&D grants or contracts.[11]

Many of the responding firms participate in the venture capital industry by holding equity positions in separate firms providing capital to new technological ventures. Overall, 9 percent of firms reported doing this, including 26 percent of large R&D-intensive companies, 6 percent of smaller R&D-intensive firms, and 7 percent of non-R&D-intensive firms. Similarly, 18 percent of large R&D-intensive firms were involved in establishing R&D limited partnerships, either as limited or general partners. Only 8 percent of the smaller firms did this, and only 3 percent of the non-R&D-intensive firms. On average, a firm engaged in 1.5 such partnerships. Both venture capital investment and involvement in R&D partnerships are means by which companies intend to exploit new technological developments.

### Technological Innovation in Individual Technologies

For a few technologies, results are available on the production of innovations over a period of time. Estimates thus can be made of the rates of innovative output in these technologies and also of output quality. The data are based on a survey of innovations published in the relevant technical journals in the indicated years.[12] Two industries are shown, chemicals and textiles. They were selected because, although productivity growth declined in the 1970's in the chemical industry and increased in textiles,[13] productivity trends for both industries seem to be largely due to the rate of production of innovations.[14]

Chemical technologies are divided into chemical products (new materials), chemical processes, process equipment, and process instruments. (See table 6-5.) These are considered the main types of technology of interest to the chemical industry.[15] New materials and processes are most likely to come from the industry itself, equipment and instrumentation often come from supplier industries. There was almost a 90-percent drop in the number of product innovations from the first period to the second. (See table 6-5.) More relevant to productivity, there was a drop of 17 percent in process innovations, 47 percent in equipment innovations, and 39 percent in instruments, which parallels the observed productivity drop.

Incomplete results suggest that many of the process innovations in the second and third periods were pollution- and energy-related rather than productivity-en-

[10]This includes all grants and contracts to U.S. institutions to support research staff or students, but excludes grants for management or social science research, grants for the arts and other purposes not related to industrial research, unrestricted grants for research, teaching, or student aid, and consulting contracts made directly with university personnel.

[11]University-industry interactions are discussed further in chapter 5, "Academic R&D and Basic Research. Patterns of Performance."

[12]For the method, see Bailey and Chakrabarti (1985), pp. 609-639

[13]Specifically, multi-factor productivity in the chemical industry (adjusted for changes in capacity utilization) dropped from 3.10 percent per year in 1965-73 to 1.91 percent per year in 1973-79, returning to 2.53 percent per year in 1980-82. In textiles, the corresponding numbers were 2.73, 3.56, and 3.38. See Bailey and Chakrabarti (1985), p. 615.

[14]See Bailey and Chakrabarti (1985), p. 630, for the data. Additional reasons are given for the productivity slowdown, including a decrease in the rate of output growth that led to underutilization of capital in capital-intensive industries. The declining rate of innovative output growth in turn is attributed to the business cycle, foreign competition, and higher energy prices.

[15]This industry is defined as Standard Industrial Class 28, excluding the drug industry (SIC 283).

**Table 6-5. Introduction of innovations in chemical technologies**

| Period | Chemical products | Chemical processes | Equipment | Process instruments |
|---|---|---|---|---|
| | Rate of introduction of innovations — Average number per year | | | |
| 1967-73 | 322.3 | 39.0 | 105.0 | 29.6 |
| 1974-79 | 39.0 | 32.3 | 54.7 | 18.2 |
| 1980-82 | 64.0 | 34.7 | 101.3 | 54.0 |
| | Fraction of innovations that are "radical innovations" or "major technical changes" in each period — Percent | | | |
| 1967-73 | 0.8 | 8.1 | 6.0 | 14.5 |
| 1974-79 | 0.4 | 8.0 | 0.6 | 10.1 |
| 1980-82 | 0.0 | 6.7 | 1.3 | 5.6 |

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference, July 7-9, 1987

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hancing.[16] These innovations would not ordinarily lead to savings in capital and labor, and would not contribute to productivity. The decline in productivity-enhancing process innovations was thus even greater than 18 percent. The period from 1980 to 1982 was too short (and too turbulent economically) to permit definite conclusions to be drawn. Still, it seems that a recovery in innovation may have occurred, corresponding to the observed recovery in productivity.

Each of these innovations was also rated by experts in terms of its degree of novelty. Four ratings were permitted: radical innovation, major technical change, improvement of existing technology, and imitation of existing technology. The two highest ratings were combined in order to show trends in high-quality innovations as a supplement to the trends in the total number of innovations. (See table 6-5.)

Except for process innovations, the trend is downward, with each time period showing fewer high-quality innovations than the previous one. Some of this may be because experts rated more recent innovations lower since there had not been sufficient time to demonstrate the innovations' importance. Still, the general downward trend seems to be fairly pronounced. A lower quality of process, equipment, and instrument innovations may also have contributed to a lowering of chemical industry productivity—or may do so in the future.

Within the textile industry,[17] there was no drop in productivity in the 1970's. This is apparently due to the continued introduction of equipment innovations. (See table 6-6.) Equipment and instrument innovations usually originate with supplier companies, rather than with textile companies themselves. Similarly, fiber, finish, and dye innovations normally come from chemical companies. The role of textile mills' own R&D is to adapt these innovations for their own production purposes, to work with suppliers in major development of equipment and instruments, and to produce textile process innovations.

Some decrease is shown in process, fiber, and instrument innovations. Fiber innovations have had a considerable effect on industry productivity in that the newer manmade fibers require far fewer processing steps and can be spun and woven much more rapidly than natural fibers. These productivity-improving fibers had already been developed before the drop in textile fiber innovation in the 1970's. Moreover, the textile industry—unlike the chemical industry—has had a relatively low share of innovations devoted to energy saving and pollution abatement as opposed to product quality and productivity enhancement.[18] This would also tend to promote the productivity performance of textiles as compared with chemicals.

A substantial drop is shown in the quality of innovations in fibers and processes. (See table 6-6.) This drop reinforces that in the total number of innovations. If productivity in this industry has not yet been affected by these trends, it may be in the future.[19]

Since textile equipment innovations are important to the productivity of that industry, a separate study was done of the origins of recent developments in weaving equipment.[20] About 9 percent of weaving equipment innovations introduced from 1970 to 1984 were by American companies. (See table 6-7.) About twice as many were from Japan. This is in spite of the fact that the meetings at which the new equipment was displayed were largely American, so that—if anything—the data would favor American equipment.

[16] Chakrabarti (1987)

[17] This is defined as SIC 22

[18] Bailey and Chakrabarti (1985), p. 619.

[19] The most important innovations from the standpoint of productivity—those related to equipment and instruments—unfortunately could not be given consistent ratings.

[20] Data were obtained from a collection of textile trade show bulletins. See Chakrabarti (1987).

**Table 6-6. Introduction of innovations in textile technologies**

| Period | Fibers | Dyes | Finishes | Processes | Equipment | Instruments |
|---|---|---|---|---|---|---|
| | Rate of introduction of innovations — Average number per year | | | | | |
| 1967-73 | 15.0 | 109.1 | 117.7 | 16.2 | 134.5 | 53.8 |
| 1974-79 | 10.7 | 158.2 | 99.2 | 14 2 | 140.5 | 44.3 |
| 1980-82 | 3.7 | 89.0 | 68.0 | 9.3 | 154.3 | 37.2 |
| | Fraction of innovations that are "radical innovations" or "major technical changes" in each period — Percent | | | | | |
| 1967-73 | 28.5 | 0.0 | 0.2 | 12.4 | — | — |
| 1974-79 | 4.7 | 0.0 | 0.3 | 3.5 | — | — |
| 1980-82 | 0.0 | 0.0 | 0.0 | 0.0 | — | — |

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference. July 7-9, 1987

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**Table 6-7. Major weaving equipment innovations introduced between 1970 and 1984, by country of innovating company**

| Country | Number of innovations |
|---|---|
| Total | 152 |
| Japan | 27 |
| Switzerland | 21 |
| Italy | 20 |
| West Germany | 17 |
| Czechoslovakia | 14 |
| United States | 13 |
| Belgium | 11 |
| Spain | 10 |
| France | 6 |
| United Kingdom | 6 |
| Ireland | 5 |
| Soviet Union | 1 |
| Sweden | 1 |

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference, July 7-9, 1987

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## REFERENCES


Bailey, M.N. and A.K. Chakrabarti, "Innovation and Productivity in U.S. Industry," *Brookings Papers on Economic Activity*, Vol. 2:1985, pp. 609-639.

Basberg, B.L., "Foreign Patenting in the U.S. as a Technology Indicator: The Case of Norway," *Research Policy* 12 (1983), pp. 227-237.

Bosworth, D.L., "The Transfer of U.S. Technology Abroad," *Research Policy* 9 (1980), pp. 378-388.

*Business Week*, "A Deepening Commitment to R&D," (July 9, 1984), pp. 64-78.

Carpenter, M.P., F. Narin, and P. Woolf, "Citation Rates to Technologically Important Patents," *World Patent Information* (1981), pp. 160-163.

Chakrabarti, A.K., "Trends in Innovation and Productivity. The Case of Chemicals and Textiles in the U.S.," paper presented at INSEAD conference, July 7-9, 1987.

Dibner, M.D., *Biotechnology in the United States—A Report to the NSF Science Indicators Unit* (Research Triangle Park, NC: North Carolina Biotechnology Center, 1986).

Griliches, Z., "Productivity, R&D, and Basic Research at the Firm Level in the 1970's," NBER Preprint No. 721 (Cambridge, MA: National Bureau of Economic Research, Inc., 1986).

Griliches, Z., A. Pakes, and B.H. Hall, "The Value of Patents as Indicators of Inventive Activity," Working Paper No. 2083 (Cambridge, MA: National Bureau of Economic Research, Inc., 1986).

Haklisch, C.S., H.I. Fusfeld, and A.D. Levenson, *Trends in Collective Industrial Research* (New York, New York University, Graduate School of Business Administration, 1984).

Hansen, J.A., J.I. Stein, and T.S. Moore, *Survey of Industrial Innovation in the United States, Final Report* (Princeton, NJ: Audits and Surveys, February 1987)

National Governors' Association, *Technology & Growth—State Initiatives in Technological Innovation* (Washington, DC: National Governors' Association, October 1983).

National Science Foundation, "Plans for Company Funded Research and Development Show 12% Annual Increases Through 1985," *Science Resources Studies Highlights*, NSF 84-329 (Washington, DC: National Science Foundation, 1984).

National Science Foundation, *Science and Engineering Personnel. A National Overview*, NSF 85-302 (Washington, DC: National Science Foundation 1985).

National Science Foundation, "Growth in Company-Funded Research and Development Expected to Slow in 1987," *Science Resources Studies Highlights*, NSF 86-314 (Washington, DC: National Science Foundation, 1987).

Pavitt, K., "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems," *Scientometrics* 7 (1985), pp. 77-99.

Schiffel, D. and C. Kitti, "Rates of Invention: International Patent Comparisons," *Research Policy* 7 (1978), pp. 324-340.

U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development: Encouraging High-Technology Development—Background Paper #2*, OTA-BP-STI-25 (Washington, DC: U.S. Congress, February 1984).

U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1987*, 107th edition (Washington, DC: 1986).

U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (Washington, DC: February 1983).

U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast, "Review and Assessment of the OTAF Concordance Between the U.S. Patent Classification and the Standard Industrial Classification Systems: Final Report," January 1985.

Venture Economics, Inc., *Venture Capital Investment and Initial Public Offering Trends: 1984-85*, special report to the National Science Foundation (December 1985).

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# Chapter 7
# The International Markets for U.S. Technology

# The International Markets for U.S. Technology

## HIGHLIGHTS

- *In 1986, the United States imported more high-technology products than it exported.* Imports of high-technology products were $75.1 billion, while exports were $72.5 billion. This was the first time ever that the United States had experienced a trade deficit in high-technology products. (See p. 124.)
- *Exports make up a larger part of the markets for U.S. producers of high-technology products than for producers of lower-technology products.* In 1984, more than 16 percent of U.S. high-technology products were exported, compared to only 5 percent of lower-technology manufactured products. Exports accounted for more than 20 percent of aircraft and parts shipments in 1984, and more than 30 percent of office and computing machines shipments. (See p. 124.)
- *Direct investment abroad by U.S. corporations has fallen in real terms since 1980.* Furthermore, U.S. direct investment abroad has been more evenly distributed among host countries, with the United Kingdom and Canada receiving lower shares of U.S. direct investment, and Japan receiving a larger share. (See pp. 125-126.)
- *Foreign revenues—composed of sales by U.S. firm affiliates and U.S. exports—make up almost one-third of the total revenues of U.S. high-technology producers.* Almost one-half of the revenues for the office and computing machines industry came from foreign operations in 1983, with net sales by affiliates (excluding exports from parent to affiliate) accounting for more than 30 percent of total revenues. By contrast, less than 20 percent of total revenues in non-high-technology industry were accounted for by foreign sales. (See p. 127.)
- *U.S. receipts and payments for the sale of patent licenses have remained approximately constant in real terms since 1972.* Payments have tended to equal about one-fifth the level of receipts, showing that U.S. firms have been far more active sellers of technology than purchasers. The funds received from these transactions are small compared to other foreign sources of income, totaling about one-tenth of 1 percent of total foreign revenues. (See pp. 130-131.)
- *U.S. firms have tended to purchase technology licenses from Western Europe, and to sell licenses in Japan.* In 1982, Japanese nationals made more than one-third the payments received by U.S. firms, but received only about one-sixth the payments by U.S. firms. In contrast, the United Kingdom accounted for one-tenth of payments to U.S. licensors, but received about one-quarter of payments by U.S. firms. The funds received from Japanese technology purchasers were about eight times as great as U.S. technology purchasers from Japan. (See pp. 131-132.)
- *The United States continues to be the world's leading exporter of high-technology products.* In 1984, the United States accounted for more than 26 percent of high-technology exports by the world's leading economies (about the same share as in 1975), Japan accounted for about 22 percent of high-technology exports, as compared to 12 percent in 1975. (See p. 134.)
- *The U.S. share of the important aircraft and parts and market has fallen sharply, while its share of the office and computing machines market has increased.* In the aircraft industry—which accounted for 20 percent of U.S. high-technology exports in 1984—the U.S. share of exports fell from more than 60 percent in 1975 to 47 percent in 1984. In contrast, the office and computing machines industry accounted for 22 percent of U.S. high-technology exports; this represented a growth in the U.S. market share from 30 to 36 percent between 1975 and 1984. (See p. 134.)

A major share of the U.S. research and development (R&D) effort is accounted for by private firms using private funds. The presumed goal of these investments in science and technology (S/T) is to develop a technological advantage that can be exploited profitably through either (1) the sale of products and services and/or the use of processes that perform new jobs, or perform old jobs better or less expensively; (2) the production of existing goods and services at lower cost; or (3) the provision of such technological expertise to other firms. Firms' willingness to undertake expensive and risky R&D programs thus depends in part on their access to markets in which the resulting innovations can be diffused and exploited. This chapter considers indicators that identify these markets for technology, and that show how the channels U.S. firms use for the international diffusion of technology vary over time and by industry. The variance of the U.S. experience with that of other countries also is presented.

The functioning of international markets for science and technology is important for many reasons. At the most abstract level, well-functioning markets and intellectual property systems theoretically encourage an appropriate division of effort and specialization at both the national and international levels, this promotes a larger output of technological improvements, and ultimately increases the national welfare.

There are also more concrete reasons for observing the channels through which technologies are diffused. First, the health of the domestic economy is directly related to the flow of new technologies. This flow is in part a function of the flexibility of those markets where innovation is taking place—i.e., markets where new and improved products, processes, and services are being bought and sold. Second, private R&D investment and other methods of financing the innovation process depend on firms' access to markets for the resulting new products and services, and on their expected success in earning sufficient returns on the R&D investments to warrant further such investments. Third, the way in which a firm takes an innovation to market may affect the future ability to compete—both for that firm and for other U.S. enterprises. Finally, government policies may unintentionally either harm or help an unrelated S/T effort by restricting the markets through which technologies diffuse. For example, policies reflecting the national security interest in restricting technology transfers to the Soviet bloc may affect the ability of U.S. firms to exploit a technological advantage elsewhere in the world. This in turn may reduce their willingness and ability to pursue innovative programs in the future.[1]

The primary goal of this chapter is to bring together several data sets that describe the markets for technology. Many of these data sets serve an important secondary function: in describing the activities of U.S. firms in the international marketplace—particularly in the high-technology areas—they indicate the strength of U.S. firms and of the U.S. economy versus foreign competitors.

This competitiveness is a difficult but important concept, embodying the widespread concern regarding the ability of U.S. producers to export, compete against imports, and operate successfully in foreign countries. Skilled and timely exploitation of emerging technological possibilities clearly contributes to the Nation's competitiveness by generating lower costs and both new and higher-quality products. Note, however, that there are other important factors, and that the precise contributions of technology, research and development, workforce skills, and other elements cannot easily be separated or quantified. Nonetheless, examining U.S. firms' performance in the international marketplace provides some indications of the strength, sources of weakness, and importance to the total U.S. economy of the Nation's S/T system.

Research and development are expensive activities; they require firms to commit substantial resources over extended periods of time, and to assume the risk that these investments may never produce profits. The fact that the business sector supports about one-half of the total U.S. R&D effort (see appendix table 4-1) validates the belief that these investments (1) are necessary for maintaining competitive viability, (2) will on average produce returns at least as high as those available from alternative investments, and (3) will sometimes deliver dramatic financial returns.

Profitable international diffusion of an innovation whether through exports, affiliate sales, or licensing to a foreign producer—helps to finance and justify the innovator's R&D expenditures and to stimulate other investments in the innovation. The following section examines these three principal channels through which technological innovations are commercialized and subsequently transferred and exploited overseas.

## THE INTERNATIONAL DIFFUSION OF TECHNOLOGY

As mentioned above, there are three principal channels for the international diffusion of technological improvements. First, many innovations take the form of goods which can be produced in the innovator's home country and exported. Second, the innovator can invest in production facilities overseas to exploit the process/product innovation by operating a subsidiary. Third, if the innovation is patent protected or there is a set of plans, procedures, drawings, etc., enabling an independent firm to replicate the innovation the innovator may sell licenses to foreign firms.

For each of these channels, the following addresses three main issues of concern:

- How successful have U.S. firms been in their efforts to exploit technological advantages in the international marketplace?
- How has this participation changed in terms of the main channels of involvement?
- How does this involvement differ by industry?

### International Trade in High-Technology Products

Emerson advised that if one can "make a better mousetrap than his neighbors, though he builds his house in the woods the world will make a beaten path to his door." The sale abroad of "better mousetraps" continues to provide an important motivation to American inventors. Moreover, U.S. success in exporting products linked to invention and innovation is a significant indicator of the strength of the economic ties linking the United States to the international S/T system.

About 43 percent of U.S. exports of manufactured products can be classified as high technology. (See appendix table 7-1.) Thus, a great deal of trade is not directly linked to R&D, invention, or innovative activity. For instance, the U.S. may retain a competitive edge for some products because of such natural advantages as access to mineral deposits or a favorable climate; for others, there may be a historical advantage in the necessary capital equipment; in still other cases, political links to trading partners may be significant.

Ideally, then, to analyze the role of science and technology in international trade, the impact of R&D—or

[1]See National Academy of Sciences (1987).

measures of other components of the S/T effort—would be statistically analyzed to distinguish them from other variables affecting trade performance. However, fluctuations in macroeconomic variables (particularly interest rates and exchange rates between U.S. dollars and our competitors' currencies) have tended to overwhelm the statistical influence of R&D and other variables related to the S/T effort.[2] It therefore becomes necessary to rely on somewhat cruder methods.

Researchers have used a number of means to identify individual industries or product groups as "research intensive," or "high technology." These methods usually employ some measure of the R&D effort undertaken in the industry or product group, normalized for industry size.[3] However, in some industries, the relevant R&D is performed internally; in others, firms depend on the innovations of those upstream suppliers that provide input to their production processes. To address this complicated technological structure, the U.S. Department of Commerce (DOC) uses an input-output table to allocate the applied research and development expenditures of intermediate-goods producers among the appropriate final-goods producers. This allocation, when normalized by shipments, permits identification of groups of products whose total R&D intensity are significantly higher than that of other products. These product groups are known collectively as the DOC-3 high-technology products.[4] (See appendix table 7-2.)

Until 1986, the United States maintained a consistent trade surplus for the identified high-technology product groups, while generally importing more than it exported of other manufactured products. Since 1980, however, the U.S. high-technology trade surplus has declined substantially, dropping from about $30 billion (at 1982 prices[5]) in 1980 to $3 billion in 1985. In 1986, the United States experienced its first trade deficit in high-technology products, with exports of $72.5 billion and imports of $75.1 billion. (See figure O-26 in Overview and appendix table 7-1.) This deficit reflects the steady increase in U.S. imports of high-technology products: these grew in real terms at an average annual rate of about 12 percent from 1980 to 1986, while exports remained more or less constant.

For all but 1 of the last 16 years, the U.S. has imported more than it has exported of products outside the high-technology groups; in the last 6 years, this deficit has increased sharply as exports have fallen and imports have risen. This demonstrates the increasingly competitive markets for *all* U.S. manufactured goods, a condition affecting both high-technology producers and—somewhat less dramatically—the non-high-technology sector.

There is a continuing shift in the U.S. comparative advantage away from traditional manufactures and toward more R&D-reliant products. However, the tendency of high-technology and non-high-technology trade balances to move in the same directions (see figure O-26 in Overview and appendix table 7-1) reflects the significance of other factors—such as the combination of strong demand at home, relatively weak demand abroad, and the strength of the U.S. dollar vis-a-vis the currencies of U.S. competitors—confronting high-technology and non-high-technology producers alike.

Data on trade in high-technology products have been used to assess technology's contribution to economic competitiveness.[6] But international trade in products is more than an arena for testing the efficacy both of U.S. innovation and U.S. policies to promote that innovation. Trade is itself an integral part of the science and technology system. As such, it provides a means for technology diffusion and for amortizing private investments in R&D. To examine trade as a channel for the spread of technology, data on trade in high-technology products must be analyzed.

Exports make up a relatively large part of the markets for U.S.-produced high-technology goods, compared to non-high-technology products. (See figure O-27 in Overview and appendix table 7-2.) In 1984, the most recent year for which data are available, more than 16 percent of high-technology shipments were exported, while only 5 percent of other manufacturing products were sold abroad.

Of all groups of high-technology products, three—aircraft and parts, communications equipment and electronic components, and office and computing machines—account for a large and increasing share of all high-technology exports (68.1 percent in 1986, up from 59.9 percent in 1978); as well as of all manufacturing products (29.1 percent in 1986, 21.5 percent in 1980). Taken together, these three product groups are even more dependent upon foreign export markets than are all high-technology products combined, with exports accounting for about 20 percent of shipments in 1985. (See appendix table 7-2.)

The three product groups also were particularly intensive in their R&D performance. In 1985, company-funded R&D expenditures in the industries associated with these products were about $19 billion, or almost 37 percent of the total industry-funded R&D effort in the U.S.[7] This measure, however, probably understates the importance of these industries to the U.S. commercial R&D endeavor, as these industries both provide important markets for various high-technology inputs and encourage R&D expenditures in various supplier industries.

The data suggest that increased commercial R&D activities accompany increased exports. While it cannot be concluded that increased R&D leads to increased exports (or vice-versa), there are reasons to believe that the two

[2]See Hilke and Nelson (1987).

[3]R&D expenditures as a percentage of total sales, and scientists and engineers employed in R&D as a percentage of total employment are two prominent examples of this approach. See Boretsky (1982) and Kelly (1976).

[4]See Davis (1982) and U.S. Department of Commerce (1983).

[5]Since there is no deflator available specifically for high-technology trade, nor for exports in general, current-dollar data were adjusted using the gross national product (GNP) deflator. Trends in constant-dollar terms should therefore be treated as approximations.

[6]See Finan, Quick, and Sandberg (1986).

[7]See National Science Foundation, *Research and Development in Industry* (1986). Document is distributed on diskette.

are mutually reinforcing. Successful R&D improves competitiveness in foreign markets, and access to foreign markets makes innovative activities potentially more profitable; this in turn encourages and provides resources for private investment in R&D.

### International Direct Investment

Possession of a technological advantage does not necessarily mean that a firm will actively export goods, or that the export of goods will be the sole—or even the primary—way in which the firm exploits its advantage. Rather, technologically advanced firms frequently operate foreign subsidiaries and affiliates. For, although exporting products is typically an attractive approach to the international marketing of a technological advantage, tariffs and other barriers to trade in goods frequently make direct investment a more profitable choice.[8]

The choice of channels for foreign market penetration may be related to the technology's age, with innovations initially exploited through exports and production moving offshore as the product or process matures.[9] Relative costs of production in the U.S. and in foreign countries are also a factor: if these costs are substantially lower overseas, production will increasingly be transferred to the foreign affiliate, and affiliate sales will substitute for exports. Overseas direct investment may also be a response to trade barriers—if imports into a country are restricted, a firm may instead set up production facilities in that country.[10] Thus, detailed information on technologies' age and other characteristics, production costs, and countries' tariffs and other trade barriers would enable assessment of the importance of technological versus legal and political influences on diffusion channels. In the current absence of such detailed information, however, analysis of the trade and diffusion of technology and high-technology products is limited.

The possession of some advantage is a widely acknowledged rationale for establishing overseas subsidiaries.[11] This advantage may involve access to superior technology, or such other firm-specific assets as brand-name advantages and distribution networks, these latter are not easily sold or otherwise transferred to other firms.[12]

It is typically less costly to transfer technology *within* firms than *between* firms.[13] The multinational corporation that operates production facilities in several countries may thus be seen as a vehicle for the international exploitation of a technological advantage.

Data on international direct investment in manufacturing—particularly in high-technology industry—serve a similar function to data on trade. First, they reflect the technological advancement of U.S. firms as compared to that of foreign rivals. Second, the data reflect the use of this channel (international direct investment) for technology diffusion both by U.S. firms abroad and by foreign enterprises operating in the United States.

The analysis here stresses the activities of multinational enterprises in manufacturing.[14] It concentrates on the international holdings and operations of U.S. manufacturing enterprises, although some new data on direct investment in certain technology-related service industries are also explored.

*U.S. Direct Investment Abroad.* The U.S. direct investment position measures the book value of U.S. investors' equity in and outstanding debt with affiliated firms overseas.[15] It provides an indication of both the level and location of this sort of international activity by U.S. firms.

U.S. holdings of overseas affiliates in the manufacturing industries increased steadily until the middle of the 1970's, after which the net worth of these holdings fluctuated, declining in real terms since 1980.[16] (See figure 7-1). This pattern was also followed by the two major industry groups comprising the bulk of high-technology activity for which detailed data are available: chemicals and allied products and machinery (which combines the machinery—except electrical—and electric and electronic equipment industry groups).

This reduction in the real value of direct investment holdings reflects an actual withdrawal of capital by U.S. parent companies, combined with a reduced rate of increase of reinvested earnings, a reduced rate of investment in new capital, and capital losses—including those due to declines in the net value of the foreign currency denominated assets of foreign affiliates.[17] The overall direct investment position therefore can only be interpreted as a general indicator of the activity level of U.S.-based multinationals, and of the potential size of this channel for the international diffusion of technology. After a long period of steady growth, this channel has apparently shrunk in the last few years.

The geographical location of U.S. investments in overseas subsidiaries has changed substantially over the

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[8]See Mansfield, Romeo, and Wagner (1979).

[9]See Vernon (1966) and Hufbauer (1966) for early discussions of the "product cycle."

[10]See Horst (1971), pp. 1059-1072.

[11]Caves (1982), pp. 3-12 and 196-200, contains discussion and many references to theoretical and empirical work.

[12]See Teece (1986b), pp. 21-45.

[13]See Teece (1977).

[14]Rationales other than technological advantage are important for the existence of multinational enterprise in other industries. For example, the petroleum industry—which accounted for almost one-quarter of all U.S. direct investment abroad in 1986, but which performs little R&D—invests abroad primarily to gain access to crude petroleum deposits, only about 15 percent of its investment is related to wholesale or retail marketing activities. See U.S. Department of Commerce (1987b), p. 83.

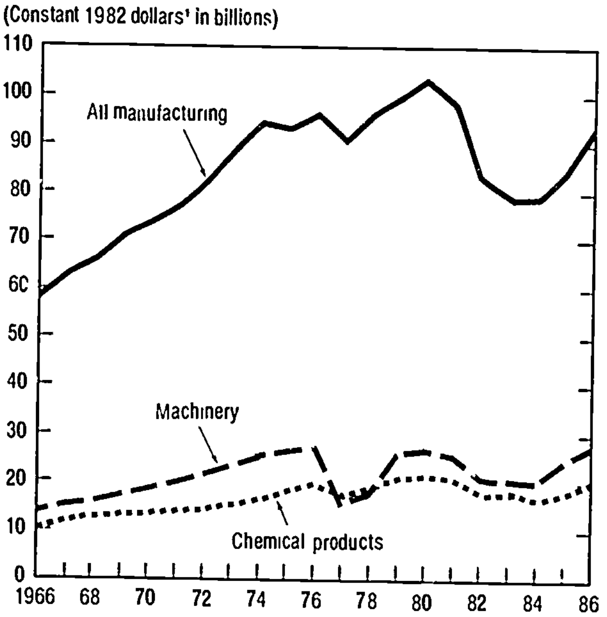
Wholesale and retail trade are two other industry groups where there is a high level of U.S. direct investment abroad While this investment may be related to the superior technologies embodied in th goods that the trading affiliates are selling, this technological com ent is accounted for in measures of the manufacturing activi hen these goods are actually produced—either through measures of U S exports of high-technology products (some of which supply the trading affiliates), or in U.S. investments in manufacturing facilities overseas.

[15]"Affiliates" are defined as firms in which the reporting U.S. parent holds an interest of at least 10 percent. See U.S. Department of Commerce (1985a), p. 4.

[16]Data are converted into constant terms using the GNP deflator As the data are already converted into U.S. dollars using the currently prevailing exchange rates, which reflect many factors besides the relative changes in prices in the different countries, the use of any single U.S. price deflator can only approximately correct the effects of inflation.

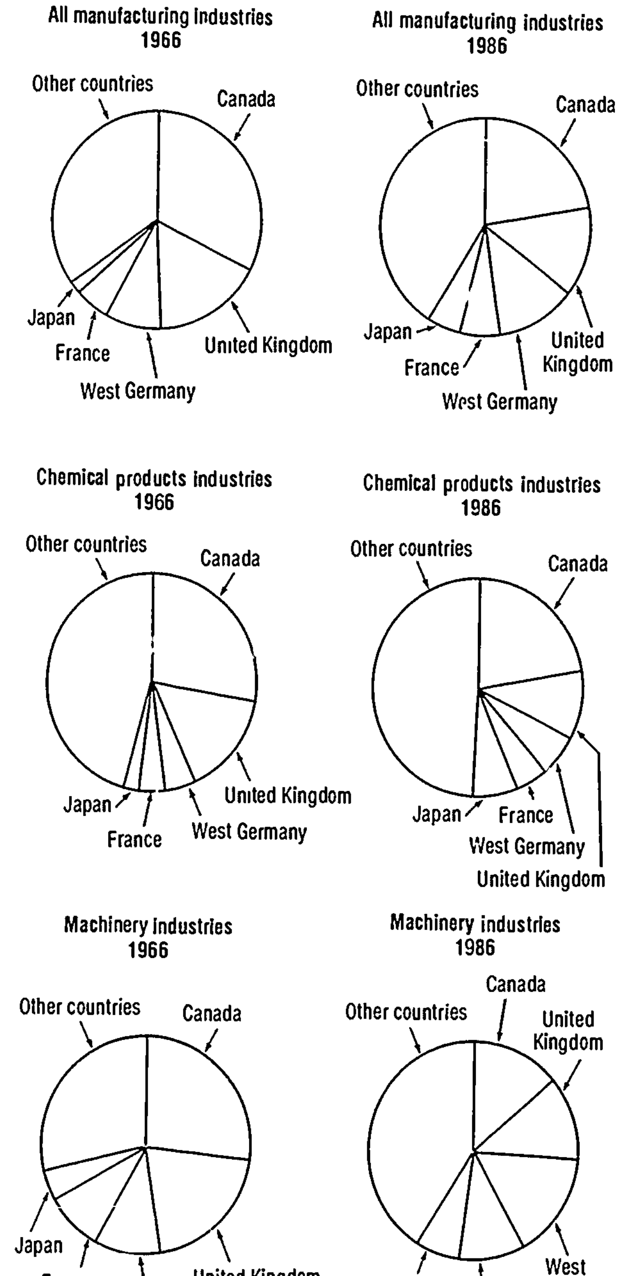
[17]See U.S. Department of Commerce (1985b), p. 31.

Figure 7-1.
**U.S. direct investment position abroad, manufacturing industries**




¹GNP implicit price deflators used to convert current to constant dollars.
See appendix table 7-3. Science & Engineering Indicators — 1987

Figure 7-2.
**U.S. direct investment position abroad, distribution by host country, major industry groups**




See appendix table 7-3 Science & Engineering Indicators — 1987

years. (See figure 7-2.) In 1966, U.S. direct investment in Canadian and British affiliates made up almost one-half of the total U.S. direct investment position in manufacturing; by 1984, this combined investment had declined to 36 percent. West Germany and France each were hosts to more than twice as much U.S. direct investment as Japan in 1966 for the manufacturing industry as a whole, and about twice as much in the machinery and chemical industries. By 1984, however, Japan and France received similar amounts of U.S. direct investment, while U.S. investments in West Germany continued to increase.

*Operations of Foreign Affiliates of U.S. Parent Firms.* More detailed information on overseas direct investment is available from a new survey of the operations of both U.S. multinationals' foreign affiliates and U.S. parent firms. This survey covers income statement and balance sheet data for parents and affiliates, broken down by industry of both parent and affiliate.[18]

This more detailed by-industry classification permits an examination of direct-investment-related activity in specific high-technology manufacturing industries, as well as in several technology-related service industries. In addition, the survey's coverage of current operations (income statement data) is closely related to the current competitive strengths and weaknesses of the parent and affiliate firms, while the balance sheet information (discussed above) concentrates on longer-term decisions

[18] Reports on the financial structure and operations of non-bank affiliates of non-bank U S companies were collected from each firm with a non-bank foreign affiliate whose assets, sales, or net income exceeded $10 million. In 1984, 1,221 U.S. manufacturing firms reported on the activities of more than 11,000 foreign affiliates. When classified by affiliate primary industrial activity, there were 6,869 affiliates in manufacturing industries, as well as 288 in three technology-related service industries. See U.S. Department of Commerce (1986a).

about the location and financial structure of parent firms' foreign activities.

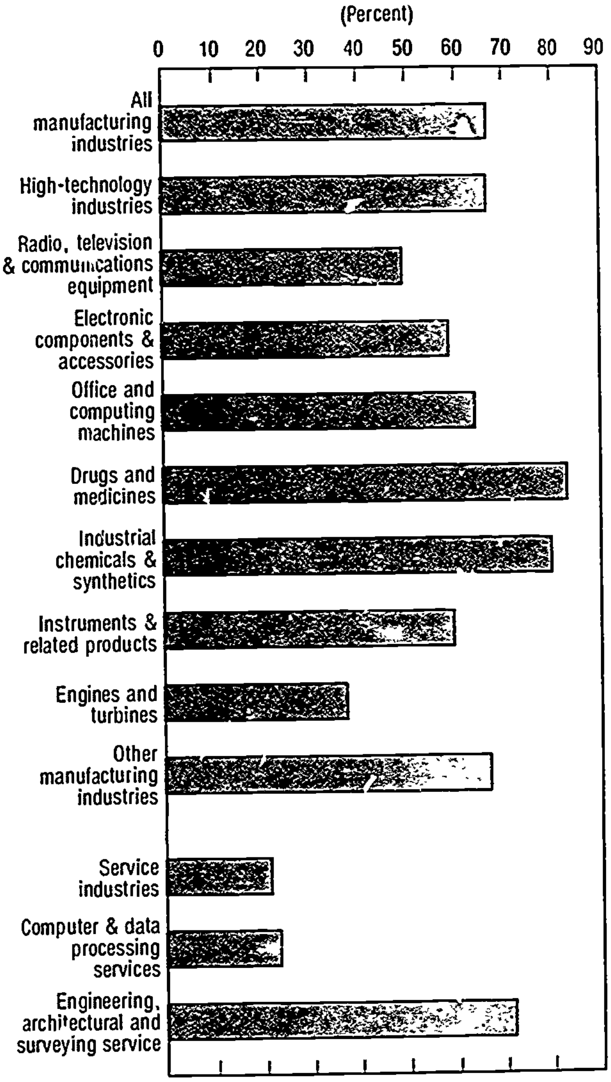
The discussion here is based on data reported by industry of affiliate for the manufacturing industries corresponding to the DOC-3 high-technology product groups. (See appendix table 7-4.) It also covers three technology-related service industries—computer and data processing services; research and development and testing laboratories; and engineering, architectural, and surveying services. Firms in these high-technology manufacturing and technology-related service industries are the ones most closely involved with the international marketing of technological advantages.

Sales of U.S. affiliates can be used to evaluate the importance of the direct investment channel for exploiting U.S. technological advantages. This is determined by calculating the ratio of net affiliate sales to total foreign revenue.[19]

Sales by overseas affiliates comprise a large part of overseas revenues for U.S. manufacturing (both high-technology[20] and non-high-technology) industries. The entire "other transportation equipment" direct investment industry class (DIIC)—which includes aircraft and parts, guided missiles and spacecraft, and several other transportation industries—accounted for less affiliate sales than any of the high-technology industries considered here except the engines and turbines industry.[21] The electronic components and accessories industry and the radio, television, and communications equipment industry also had relatively low net affiliate sales. (See figure 7-3.)

Access to foreign markets through direct investment is slightly more important for non-high-technology industries trade than for that of high-technology industries. (See figure 7-3.) However, in comparing affiliate sales to total corporate revenue,[22] this trend is reversed. In figure , ., the share of total revenues accounted for by net affiliate sales was almost twice as great in the group of

Figure 7-3.
**Sales by foreign affiliates of U.S. corporations as a percent of foreign revenue: 1984**




See appendix table 7-4 Science & Engineering Indicators — 1987

high-technology industries as in other manufacturing industries. Moreover, none of the individual high-technology industries for which data are available received a lower share of revenue from affiliate sales than the 11.5 percent of the non-high-technology manufacturing industries. Overseas affiliates are particularly important to firms in the office and computing machines and drug and medicine industries, where net affiliate sales accounted for more than 30 percent of total revenue in 1983.

The importance of foreign markets as a whole to the U.S. high-technology enterprise is indicated by comparing total sales abroad to total domestic sales. In 1984, foreign sales, made up of net affiliate sales plus exports, were equivalent to almost 32 percent of total shipments in

[19]Net affiliate sales are calculated as affiliate sales less parent firm exports to affiliates—this avoids counting twice goods exported for resale by affiliates. The sum of net affiliate sales and exports by the domestic industry is a measure of the industry's total foreign revenue.

[20]The industries defined here as high-technology are those whose direct investment industry classifications (DIIC) correspond to the DOC-3 high-technology product groups, with the following exceptions. There are no DIIC's for guided missiles and spacecraft, aircraft and parts, or ordnance and accessories. Industrial inorganic chemicals and plastic materials and synthetics are combined with industrial organic chemicals (not a DOC-3 high-technology product) to form the industrial chemicals and synthetics DIIC See Davis (1982) and U S Department of Commerce (1985a), pp 439-459

[21]See U.S. Department of Commerce (1987b), tables 2 and 17

[22]As in the discussion of high-technology exports, the sales figure used is shipments in selected industries. Total foreign revenues are the sum of exports of the corresponding high technology products plus sales of affiliates operating in the selected high-technology industries, minus imports from parents of the surveyed affiliates. The sum of net affiliate sales plus exports is then taken as a percentage of total revenue. This procedure is not correct in a strict accounting sense, as the exports are calculated on a product basis, while affiliates are classified by their primary economic activity This activity differs in many cases from that of the parent companies, which is the classification of the shipments data.

seven high-technology industries.[23] (See figure 7-4.) The office and computing machines industry led these industries with about 48 percent of shipments. The radio, television, and communications industry—with 21 percent of revenues from foreign sources—was the least "international" of U.S. high-technology industries. In contrast, non-high-technology manufacturing industries made only about 16 percent of their sales to foreign customers.

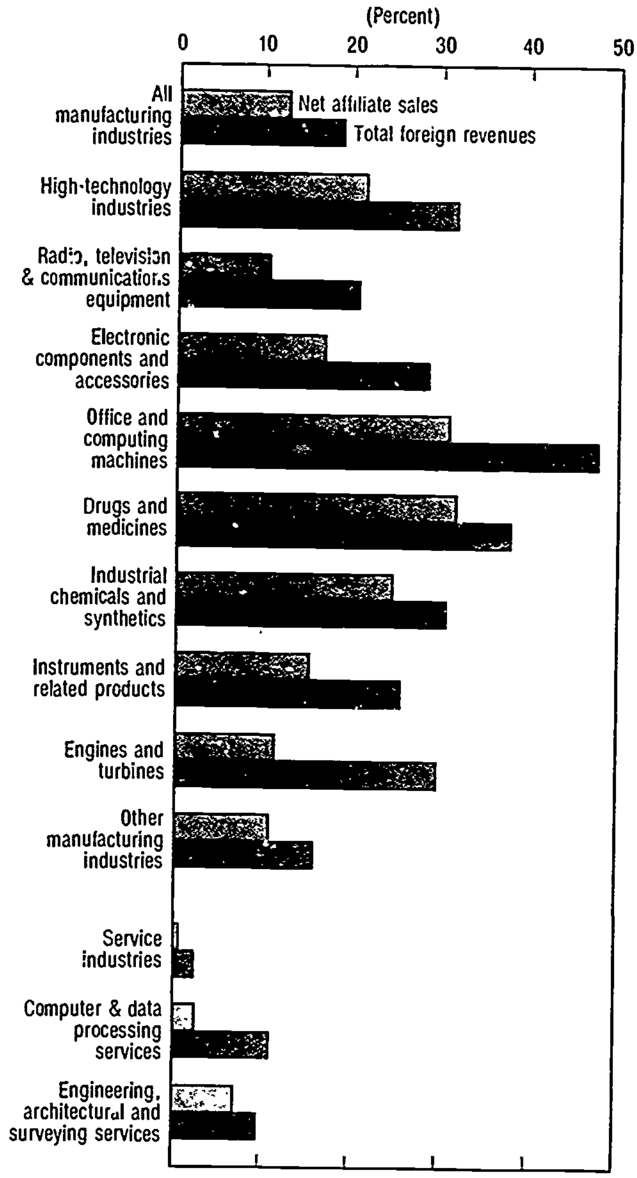
*Foreign Direct Investment in the United States.* The United States is the world's single largest recipient of international direct investment. In 1984, the U.S. received about 21 percent of all international direct investment; this was primarily from other advanced industrialized economies.[24] Investment source and industrial location indicate the role such investments play in the international diffusion of technology. For example, do these foreign investments in the U.S. correspond to transfers of foreign-origin technology into the United States? Is technology a less important part of foreign investment in the U.S. than it is of U.S. investment overseas?

In 1986, foreign direct investment holdings in U.S. manufacturing industries were worth more than $68 billion (at current prices). This represented an increase (in real terms) of 38 percent since 1981—an average annual growth rate of almost 7 percent. (See appendix table 7-5.) The distribution of these holdings by nationality of ownership is shown in figure 7-5; the great majority of these holdings belong to investors in the advanced industrialized countries.[25]

Several features stand out in this distribution of holdings. First, while Japan has experienced great success in international competition in general (and in the development of technological expertise in particular), Japanese firms account for a very small share of total foreign direct investment in the United States. Even in the machinery industries (including computers and office machines; radio, television, and communications equipment; and electronic components and accessories—three industries where major Japanese participation might be expected and which accounted for 52 percent of the foreign direct investment position in machinery in 1986),[26] Japanese investors accounted for only 6.6 percent of 1985 foreign investment in the U.S.

The level of Japanese participation in foreign direct investment in the United States mirrors the relatively low levels of U.S. direct investment in Japan. This suggests cultural, linguistic, legal, or other barriers that block the operation of multinational business between the two countries. There are a number of other explanations for

Figure 7-4.
**Net affiliate sales and total foreign revenues of U.S. corporations as a percent of total revenue: 1984**




See appendix table 7-4. Science & Engineering Indicators — 1987

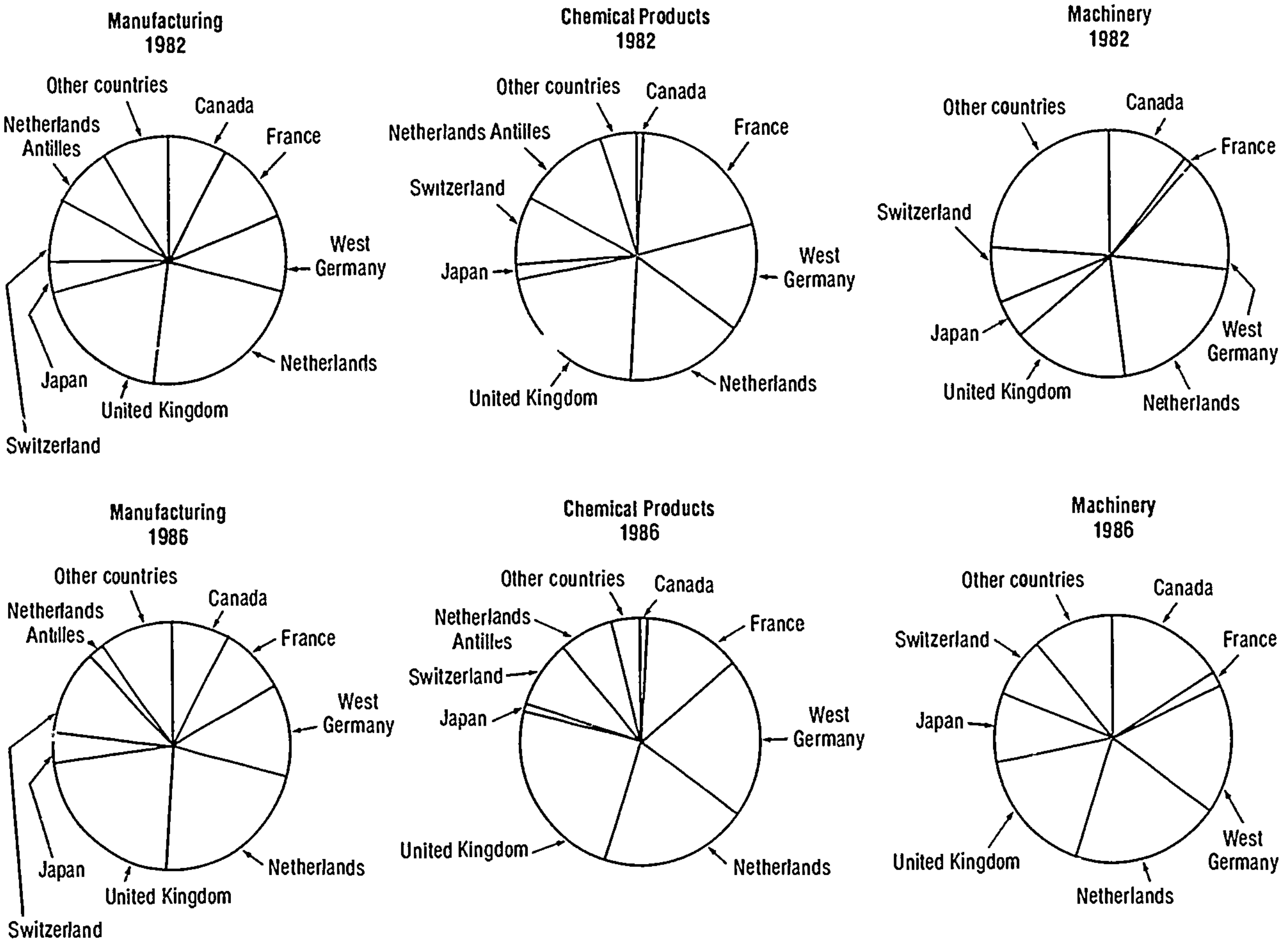
[23] The aircraft and parts and guided missiles and spacecraft industries are excluded from this analysis as data are not available for affiliate sales in these industries. It should be noted that exports alone of these products amount to more than 20 percent of shipments; including exports of these products in foreign revenues, and shipments from these industries in total revenues, leaves the ratio of high-technology revenues coming from foreign markets at more than 30 percent (See appendix tables 7-2 and 7-5.)

[24] See U.S. Department of Commerce (1984), pp. 45, 61, and updates from Office of Trade and Investment Analysis, International Trade Administration.

[25] The substantial distribution attributed to the Netherlands Antilles includes large holdings by investors from other advanced industrialized countries (including the U.S.). However, even when tracing assets to the country of "ultimate beneficial owner," the Netherlands Antilles remains an important source of foreign direct investment, since the majority of investing firms are largely incorporated in the Netherlands Antilles, and their ownership cannot be further identified. See Shea (1986).

[26] See U.S. Department of Commerce (1987a), table 23, p. 98.

Figure 7-5.
**Foreign direct investment in the United States in manufacturing, distribution by country: 1982, 1986**




See appendix table 7-5

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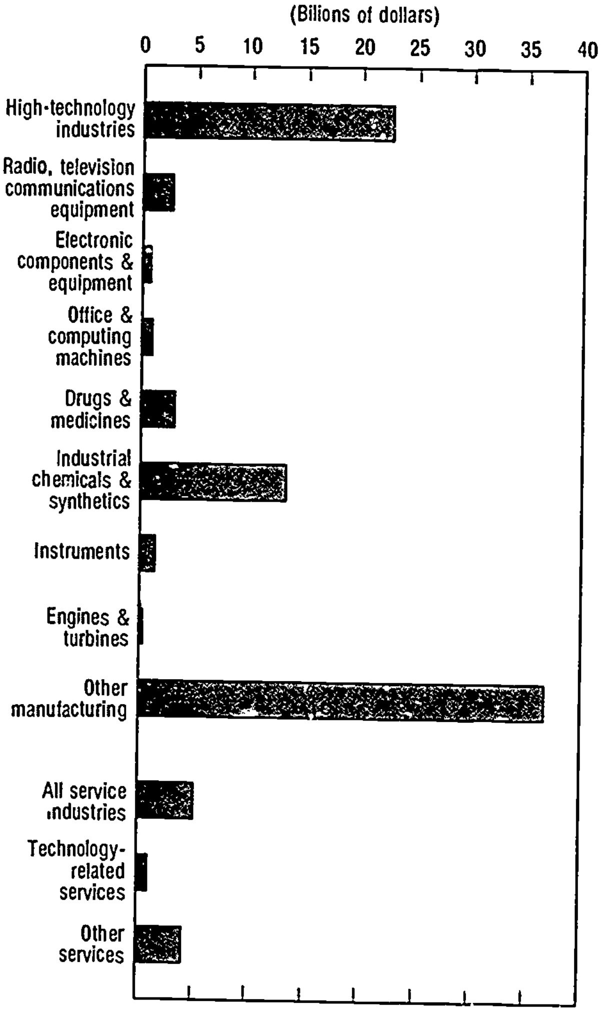
these apparently low levels of investment. For instance, some Japanese investment in manufacturing industries—particularly in the automobile industry—is classified as wholesale trade. This is because the industrial classification methodology is based on the enterprise's principal activity. Also, foreign direct investment in Japan was—at least until the late 1970's—restricted by policy; concurrent restrictions on Japan's outflow of capital made outside direct investment more difficult.

A second important feature of foreign direct investment is the relatively small role of Canadian direct investment. (See figure 7-5.) Although Canada is the most important host for U.S. direct investment abroad, and in spite of very strong cultural ties between the two countries, Canadians own a relatively small share of the foreign direct investment position in the United States. In contrast, the Netherlands is the largest source of foreign direct investment in U.S. manufacturing. This activity is broadly spread. Dutch investors account for major shares of the total foreign position in both chemical products and machinery. Switzerland is another relatively small country with a major position in the United States; France, on the other hand, is somewhat less active (relative to its size) in the United States, particularly in machinery.

A detailed breakdown by industry is available for the total foreign direct investment position in the United States. Foreign investors are not particularly active in most of the high-technology industries, with combined direct investment holdings of about $26 billion in 1986. (See figure 7-6 and appendix table 7-6.) More than one-half of this investment was in the industrial chemicals and synthetics industry. Non-high-technology industries account for almost two-thirds of total foreign direct investment in U.S. manufacturing industries, and about 80 percent of the foreign holdings in U.S. service industries.

The two countries that appear to offer the U.S. the closest competition in global markets for technology—West Germany and Japan—have smaller presences here than would be expected if direct investment in the United

Figure 7-6.
**Foreign direct investment in the U.S. manufacturing industries: 1986**




See appendix table 7-6 Science & Engineering Indicators — 1987

States were primarily a function of technological competitiveness. Furthermore, foreign direct investment in the United States is weighted toward those industries that, at least in the United States, are not high-technology. In contrast, the pattern of U.S. direct investment abroad seems to be strongly related to technological strength, or at least to research and development effort. This latter correlation is not unexpected, since industries where U.S. corporations put their greatest technological efforts—the high-technology industries—should offer fewer opportunities to foreign firms for profitable direct investment in U.S. production facilities.

## Patent Licenses and Technology Agreements

The preceding sections have concentrated on commerce, primarily related to technology, where the exploiting firm has traded on its technological advantage without actually selling control of the technology to other firms. The sale of high-technology products involves the export of so-called "embodied technology." These products were selected because they reflect significantly greater R&D expenditures—both by the producing industries and by industries upstream—than do non-high-technology products. The sellers of these goods then trade upon the greater sophistication and serviceability of their products. In time, other firms—both at home and in other countries—imitate the innovator's techniques, and the competitive advantage from technological innovation dissipates. There is thus a transfer of technology through two channels: (1) the technology-embodying goods that are sold, and (2) the information these goods carry which ultimately permits a rival to copy or improve upon them.

There is also a twofold transfer of technology related to direct investment. First, the innovative firm sets up production of its technology-embodying product in the market, creating a transfer of technology analogous to that accompanying high-technology product export. Second, there is a transfer of "disembodied technology." In setting up production facilities, the investing firm brings a panoply of formal and informal knowledge (know-how) associated with the technology's use. This know-how ranges from designs and blueprints to production experience and knowledge of appropriate marketing strategies. As with exporting, there is undoubtedly a leakage of technology to the firm's potential rivals. Moreover, the wider the distribution of a good, the more likely it is to be seen by an imitator, and the more visible the market the imitator may hope to capture.

Exporting and investing abroad are very different approaches to the international transfer of technology, and are pursued to different degrees in different industries. However, both strategies have an important element in common: technology leakages to potential competitors are not deliberate, and those leakages that do occur are largely an inevitable result of succesful marketing.

Exporting products and investing in production facilities abroad are not the only way in which firms can profit from their technological advantages. Firms also may simply sell their rights to an invention, and/or provide technical information on an invention's production or use, to an independent firm. This latter firm will undertake the product's improvement, production, and/or marketing, paying license fees and royalties to the original firm; these are frequently proportional to product sales.

Such arrangements have both advantages and drawbacks. On the positive side, the firm selling its technology may lack access to the resources necessary to fully exploit the technology, such as related technologies, raw material or capital resources, marketing expertise in the relevant country or industry, etc. Furthermore, firms may be able to exchange licenses with other firms, thereby gaining access to a new pool of knowledge.

On the other hand, by selling patent licenses and associated technical information and blueprints, the licensing firm makes the potential imitator's job much easier. The licensor sells not just technical information, but also partial control over the technology. Science and technology are cumulative, advances typically require mastery of the existing art. A cost of patent protection is the information that is disclosed in the patent document, if a license to the patent is also sold, the imitator need not wait for patent expiration to gain production experience. Additionally, the sale of nonpatent plans, specifications, operating procedures, and so on, further accelerates the imitator's mastery of the existing art.

To some extent, firms' receipts and payments of firms for patents and technical exchange agreements represent a pure indicator of technological prowess. Particularly between unaffiliated firms—where prices are set through some market-related bargaining process—they reflect only the exchange of technology, totally separate from individual products or a firm's internal characteristics. Thus uncluttered by other elements of competitiveness, these receipts and payments may be seen correctly as an "output" indicator—one of the few statistics describing the production and exchange of knowledge. However, while the data describing patent license sales and exchanges reflect technological merit, the problems associated with the underlying transaction suggest that they also be viewed as indicators of constraints upon technology transfer channels.

When possible, it is appropriate to examine receipts and payments associated with technology exchanges between independent firms, rather than between affiliates, since there is no reason to believe that the prices a firm sets for its internal transactions bear a close relationship to market values. Unfortunately, however, transactions between affiliates are not always reported separately from those between independent firms. When such combined data are used, it should be remembered that they may reflect a firm's internal accounting practices as well as technology transactions between firms.

Since 1972, both U.S. receipts and U.S. payments of royalties and fees associated with unaffiliated foreigners have remained more or less constant in real terms. receipts have fluctuated around $1.5 billion at 1982 prices, and payments around $300 million. (See appendix table 7-7.) During the last decade, U.S. receipts for technology have generally been about five times as great as payments.

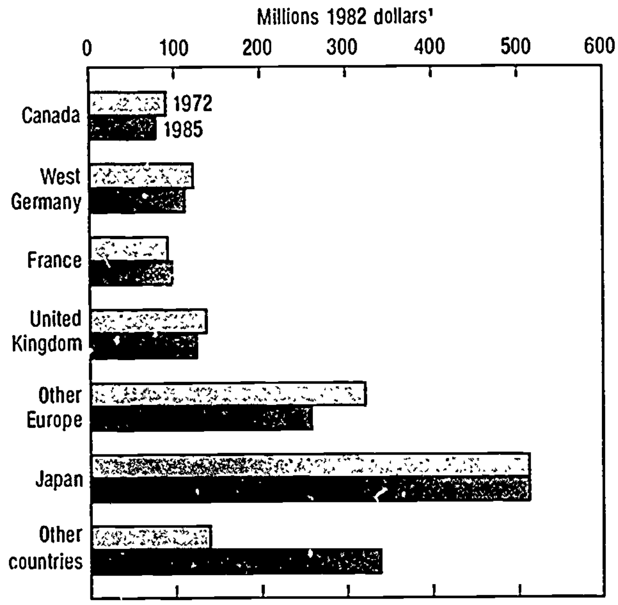
Compared to the other two channels for technology diffusion, licensing and other technology agreements are quite small, making up less than one-half of 1 percent of total foreign operations in 1984. (See appendix tables 7-4 and 7-7.) These data, however, represent a pure flow of technology. Technology transferred in this way provides a means for the foreign purchaser to overcome a technological lag; at the same time, the purchaser may improve its current ability to compete, as well as its ability to participate in later improvements of the products and/or processes involved. Sellers of such technology gain a percentage of sales in foreign markets that they may have been unwilling or unable to exploit either through exports or direct investment in those markets.

These bilateral transactions in patent licenses and other technology exchange agreements between U.S. firms and the unaffiliated nationals of particular countries thus provide a useful indication both of the nature of technology transfers between the two countries, and of the success the countries are experiencing in acquiring—and presumably using—the other's technology.

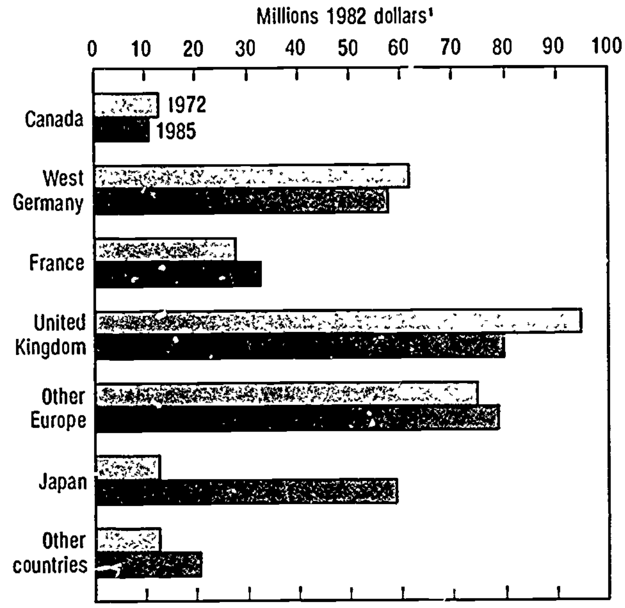
There is considerable variation in the technological relations between the United States and different countries. (See figure 7-7.) Japanese nationals in 1985 made more than one-third of the payments received by U.S firms, but received only about one-sixth of U.S. payments. In contrast, nationals of the United Kingdom

Figure 7-7.

**U.S receipts of royalties and fees from unaffiliated foreigners: 1972 and 1985**




**U.S payments of royalties and fees to unaffiliated foreigners: 1972 and 1985**




¹GNP implicit price deflators used to convert current to constant dollars.

See appendix table 7-7. Science & Engineering Indicators — 1987



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accounted for 8 percent of U.S. technology receipts, but received more than 23 percent of U.S. payments. U.S. receipts from U.K. nationals were about 55 percent greater than payments to the United Kingdom in 1985; in contrast, receipts from Japanese purchasers were more than 700 percent greater than payments. Overall, U.S. receipts were about 3.5 times as great as U.S. payments.

Given the size and strength of the U.S. science and technology system, the positive technological balance of payments between the United States and the rest of the world is not surprising. A surplus between the United States and even as technologically sophisticated a country as Japan is to be expected; however, the size of the U.S. surplus with Japan requires further analysis. Perhaps Japanese producers are superior at practical application of ideas and inventions; or U.S. firms are better at invention than innovation; or there are legal, political, or other obstacles that prevent U.S. producers from putting their inventions into practice, and that require the participation of Japanese licensees. There also may be other, more innocuous, reasons for the strong tendency of U.S. inventors to license their technologies in Japan.

The technology flows between the United States and Japan, however, are considerably less one-sided than they used to be. After accounting for inflation, U.S. technology receipts from unaffiliated Japanese entities have remained constant since 1972, while the level of payments in 1985 was more than 4.5 times as great as the 1972 level.

U.S. payments to technology sellers in the United Kingdom are larger than might be expected given the size of the British R&D endeavor. In 1983, United Kingdom R&D expenditures were less than one-half those made in Japan, and about two-thirds the level in West Germany; nonetheless, the U.K. was easily the largest recipient of U.S. technology payments. (See appendix table 4-1 for data on R&D expenditures.)

The close cultural and linguistic ties between the United States and the United Kingdom might explain the high level of British technology sales. But this explanation would also predict particularly large technology transactions between the United States and Canada, and a high level of U.K. purchases of U.S. technology—neither of which is in fact the case. For example, U.S. technology receipts from the United Kingdom are only one and one-half times as great as payments, so that the bilateral technological payments between the U.K. and the U.S. are closer to balance than are the payments between the United States and any other country.

Japan and the United Kingdom represent the extremes of the U.S. technology transaction activity (at least among the largest industrialized countries). Comparing these two sets of technology transactions shows that the U.S. both imports and exports disembodied technology, without an accompanying flow of goods or investments.

The total flows of receipts and payments of royalties and license fees include both new agreements and those made in previous periods which are still in force. A history of U.S. inventive strength, and the past willingness of U.S. inventors to transfer their technology to overseas entrepreneurs, may overshadow current efforts by U.S. firms to both import and adopt foreign technology, and to use other channels to transfer and exploit their own advantages overseas. The U.S. data discussed above do not distinguish between new and old technology agreements, and thus may reflect this slow responsiveness to current conditions.

To partially rectify this difficulty, there is a recent Japanese government survey of the technology purchase and sale activities of Japanese firms. This has shed light on the year-by-year transactions between Japanese and U.S. firms (and between Japanese firms and nationals of the other large advanced industrialized countries). While these data reflect only some of each year's technology transactions between Japan and the rest of the world—and of course contain no information about transactions between the United States and countries other than Japan—they do provide additional details about the relatively high level of technology sales made by U.S. firms to Japan, as well as U.S. technology purchases from Japan.

Table 7-1 shows the share of new transactions in the total Japanese receipts from sales and payments for purchases of technology. Improvement in the Japanese technology bases should reduce Japanese purchases and increase Japanese sales relative to their historical levels. In fact, although there is considerable year-to-year fluctuation in the share of Japanese technology receipts and payments attributable to new agreements, the tendency seems to be in the opposite direction. As new Japanese technology purchases have increased (relative to the existing level of technology exchange agreements), the value of new Japanese technology sales has increased less rapidly than has the total of annual Japanese receipts from all technology agreements. Thus, there is little evidence that strong Japanese performance in developing commercial technology is being matched by licensing that technology to non-Japanese producers abroad, or by reduced purchases of technology licenses from foreign inventors.

**Table 7-1. New agreements as a percent of total technology transfer agreements between Japan and the United States and other major countries: 1975, 1980, 1985**

| | 1975 | 1980 | 1985 |
|---|---|---|---|
| | Percent | | |
| Technology sales to: | | | |
| United States | 19 | 28 | 14 |
| Other major countries | 58 | 42 | 43 |
| Technology purchases from: | | | |
| United States | 7 | 13 | 11 |
| Other major countries | 8 | 9 | 13 |

See appendix tables 7-8, 7-9.

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## TECHNOLOGY AND U.S. COMPETITIVENESS

Science and technology are not only influenced by the national and international trading system, but are also a source of competitive strength and success within that system. The contributions of research and development and other S/E activities to the Nation's economic performance—specifically to the ability of U.S. producers to compete in both domestic and international markets—are one of the rationales for Federal support of science and engineering. By examining data on the marketing of technological advantages, this section assesses S/E's contribution to trade performance, and identifies areas of U.S. strength and weakness as compared to other countries.

Technological proficiency does not guarantee success in the international marketplace. A firm also may need access to attractive financing packages, advertising and marketing skills, manufacturing expertise, etc Without such complementary assets, better equipped imitating firms may be able to overtake the innovating firm, gaining the advantage ascribed to being "competitive."[27]

This section discusses "competitiveness," broadly defined as the ability of U.S. firms to sell products abroad and in domestic markets. Two aspects of competitiveness—trade and firm—are of particular interest Trade competitiveness is narrowly defined as the ability of U.S. producers to export and to compete with imports in domestic markets. Firm competitiveness refers to the ability of U.S.-based firms to compete at home and abroad. In both cases, a crucial element of competitiveness is producers' ability to increase earnings while meeting the competition in international markets[28]

These two types of competitiveness are strongly related. The "product cycle" hypothesis suggests that the technological innovations that later lead to foreign direct investment and overseas production are initially produced and sold domestically, and then exported.[29] Firm competitiveness is thus initially exhibited through trading performance (described here as trade competitiveness). Less directly, the ability to capture domestic and export markets in the early stages of an innovation's life—trade competitiveness—may be a necessary condition for the innovative effort which enhances a firm's overall competitive position.

As measures of the strength of the Nation's science and technology system, the two aspects of competitiveness must be treated separately. Trade competitiveness results not just from superior technology, but also from those factors that determine the market price for goods of a given quality In particular, trade competitiveness is largely a function of the exchange rates between the dollar and the currencies of the other major trading countries. Firm competitiveness, on the other hand, is less directly related to the Nation's economic health, but has stronger ties to technological prowess. (Other factors, such as brand-name advantages, labor and marketing skills, and managerial excellence, are also relevant.)

In assessing the competitive strengths and weaknesses of U.S. commercial science and technology, changes in the overall competitiveness (broadly defined) of U.S. technology must be distinguished from shifts in the channels (discussed above) used to exploit technological advantages internationally. Data on each of the three channels are therefore examined, both in terms of the different aspects of competitiveness, and as evidence of the overall strength of the U.S. commercial S/T system.

### High-Technology Trade Competitiveness

The combination of slower growth in U.S. exports of high-technology products and the steady increase of imports has led to a dramatic decline in the U.S. high-technology trade surplus. Specifically, trade dropped from about $31 billion in 1981 (1982 prices) to $3 billion in 1985, and a deficit of $2.6 billion in 1986. (See figure O-26 in Overview.) This stark picture has led to widespread concern about a loss of U.S. competitiveness in these leading industries.

There has been a larger loss in U.S. trade competitiveness in all manufactured products, besides that in the high-technology product groups. Whether this implies a loss of U.S. technological leadership depends in part on whether the product groups described as "high-technology" are in fact those closest to the leading edges of technology. Since these high-technology product groups are defined at the three-digit standard industrial classification (SIC) level, each group contains products of varying levels of technological sophistication. A loss in U.S. market share in a product group may in fact be an increase in the volume of the less sophisticated goods in the product group, which might be produced primarily in other countries. It may also reflect overseas production of goods that had once been near the leading edge of technology, but that are now standardized and can be produced offshore. At the same time, a U.S. technological lead might exist or be developing in products that lie outside those defined as high-technology.

In the rapidly changing commercial world, all three of these explanations apply at various times. The first can be described as a loss of U.S. trade competitiveness, without implying a loss of U.S. technological leadership, the second is a consequence of the evolution of products and technology. The third entails unobserved strength in U.S. commercial science and technology.

If the U.S. is indeed losing its technological leadership, there should be a shift in market share from the United States to its nearest technological competitors—i.e., the other advanced industrialized countries of the Organisation for Economic Co-operation and Development (OECD). A loss of market share in individual high-technology products might reflect increased age and standardization of the technologies used or included in those products, thus permitting more countries to compete effectively. Loss of market share in this case need not reflect movement of U.S. firms away from the technological frontier, but instead, broader participation in technology.

[27]See Teece (1986a), pp. 285-305.

[28]For a related definition which differentiates between "corporate competitiveness" and "national competitiveness," see Cohen, Teece, Tyson, and Zysman (1984), p. 2.

[29]See Vernon (1966) and Hufbauer (1966).

If, however, the weaker U.S. trade performance in high-technology products does reflect a weaker ability to perform at the technological frontier, then loss of competitiveness would be most severe in those product groups that most intensively perform and use applied research and development By combining analysis of national market shares in high-technology products and U.S. performance with regard to a smaller subset of these products, the issue of technological leadership can be disentangled somewhat from the more general issue of the loss of U.S. trade competitiveness.

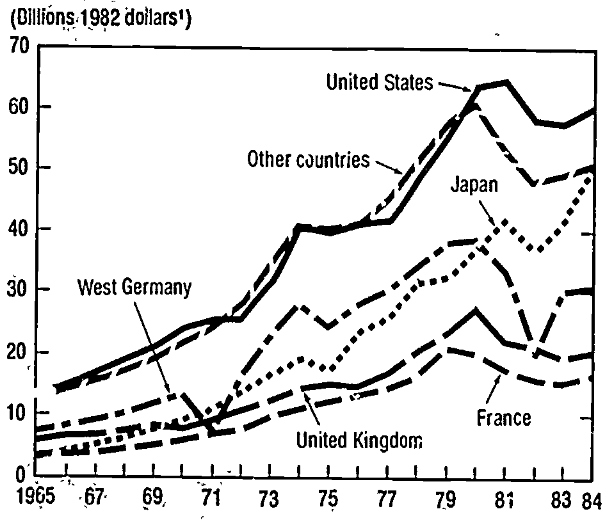
Since 1965, the United States has accounted for between 23 and 30 percent of world exports of high-technology products.[30] In 1984, the latest year for which data are available, the United States was still the world's largest exporter of high-technology products. Although the U.S. share of the world market for high-technology goods declined from around 30 percent in the late 1960's to about 25 percent in the late 1970's, the U.S. share has more recently hovered around 27 percent. (See appendix table 7-10.) Furthermore, exports of high-technology products have tended to increase for all of the largest industrialized economies, although there was a downturn for all countries in the early 1980's, coincident with economic recessions for the United States and most of its trading partners.[31] (See figure 7-8.)

Thus, in spite of the relatively difficult competitive situation that has faced U.S. producers in recent years,

[30] "World exports" are defined here as these exports reported to the United Nations by 14 major countries. (See appendix table 7-10.)

[31] Council of Economic Advisers (1985), pp. 28 and 99.

Figure 7-8.
**Exports of high-technology products, by selected countries**




¹GNP implicit price deflators used to convert current to constant dollars.
See appendix table 7-10. Science & Engineering Indicators — 1987

U.S. exporters have been relatively successful at defending—and in some cases increasing—their market shares, at least in relation to their competitors in the other major industrialized countries.

The market shares discussed here include the bulk of the world's trade of high-technology products. However, these data omit those "newly industrialized countries" (NIC's)—e.g., Taiwan, Singapore, South Korea, Brazil, and Mexico—that are increasingly active in this area. For example, U.S. imports from the East Asian NIC's increased by more than 115 percent in real terms between 1980 and 1986, during a period when total U.S. imports of high-technology products from all countries grew by about 100 percent. In 1986, the East Asian NIC's accounted for about 18 percent of U.S. imports of these products, making these countries key participants in at least the U.S. high-technology markets.[32] (See appendix table 7-11.)

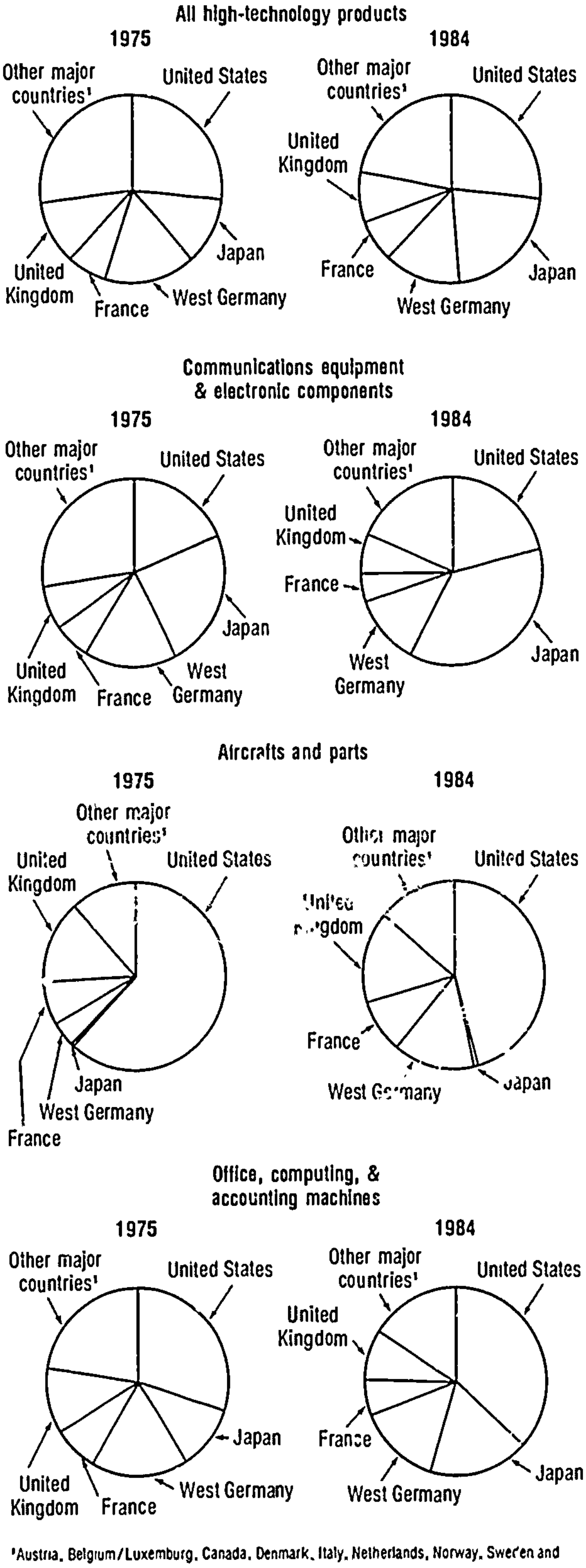
In the earlier discussion of trade in high-technology products as a channel for the international diffusion of technology, three high-technology product groups—aircraft and parts, communications equipment and electronic components, and office and computing machines—were identified as being both intensively exported and intensive in their performance and use of applied research and development. U.S. exporters have had mixed success in defending their market shares in these three product groups. While the U.S. share of the high-technology product markets as a whole was about the same in 1984 as in 1975, it increased in the communications equipment and electronic components and office and computing machines groups. but fell sharply in the aircraft and parts group. (See figure 7-9.) The latter decline probably largely reflects competition from the Western European Airbus commercial transports, while the other two product groups demonstrate U.S. strength in computers and microelectronics.

It is in these two groups, and in high-technology products as a whole, that the Japanese challenge is manifested. Japan maintains the largest market share in communications equipment and electronic components (which includes radio and television equipment, as well as more sophisticated electronic circuitry). It also increased its share of office machines and computers exports from 11 percent in 1975, less than either West Germany or the United Kingdom, to almost 18 percent in 1982; this made Japan the second-leading computer exporter in the world.

These data provide little evidence of a generalized loss of U.S. technological leadership to any particular country. Instead, the loss of U.S. trade competitiveness in individual areas is caused by the appearance of strong rivals—Western Europe in the aircraft industry and Japan in electronics. There has also been a shift of markets from the U.S. to producers from the NIC's, presumably because an aging technological base opens a competitive advantage for low-cost operations. However, nowhere is there a clear loss of U.S. technological leadership, rather,

[32] See U S Department of Commerce (1986b), and Finan, Quick, and Sandberg (1986).

Figure 7-9.
**Export market shares, selected high-technology products**




¹Austria, Belgium/Luxemburg, Canada, Denmark, Italy, Netherlands, Norway, Sweden and Switzerland
See appendix table 7-12.

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it appears that the competition is catching up. Moreover, the race for new technologies is being run faster than ever before.

## Direct Investment and Firm Competitiveness

Ideally, to analyze firm competitiveness, the profitability of U.S. firms engaged in international direct investment would be examined in conjunction with investment levels or total sales by overseas subsidiaries. In the absence of data on the profitability of direct investment, however, such analysis is limited to comparing levels of activity related to direct investment. Assuming that, overall, such activity meets minimum profitability criteria (otherwise it would not be undertaken), comparisons of direct investments undertaken by nationals of different countries can help to identify investment changes resulting from firms' competitive positions rather than from broader changes in the international environment.

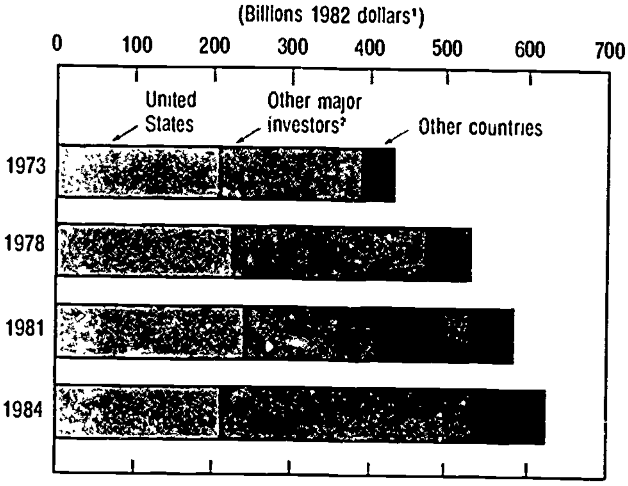
The U.S. direct investment position abroad in manufacturing industries grew steadily until the mid-1970's, and has declined in real terms since 1980. (See figure 7-1.) A similar pattern is apparent for the United States with regard to direct investment overseas in all industries:[11] in 1984, the U.S. position had fallen by $30 billion (at 1982 prices) since 1981. During the same period, however, the direct investment positions of most of the other major investing countries had increased substantially, so that direct investment throughout the world had increased at an average rate of about 3.4 percent per year (after inflation) since 1973. (See figure 7-10 and appendix table 7-13.) The increase in holdings is broadly based; moreover, of the countries for which data are separately available, only firms based in Switzerland have decreased their holdings.

The stock of international direct investment held by developed countries other than the United States increased by about $75 billion between 1980 and 1984. During the same period, foreign direct investments in the U.S. from other developed countries increased by about $70 billion. As the growth in direct investment holdings by firms based outside the United States has taken place almost entirely within the United States, it is possible that U.S. firms are suffering from a climate unfavorable to international direct investment. There also may be conditions that are particularly unfavorable to U.S.-based direct investment, or there may be slippage in the technological competitiveness of U.S. firms. While nontechnological conditions for international direct investment cannot be delineated here, the importance of foreign markets to U.S. firms suggests the relevance of the question to U.S. science and engineering policy.

Does the weakening of the U.S. position in international direct investment indicate a weakening of our technological competitiveness, or simply a shrinkage of the channels for international marketing of innovations? To determine this, it is useful to examine the direct invest-

[11]Data on the position in manufacturing are not available for countries other than the United States.

Figure 7-10.
**Value of international direct investment holdings, by ownership of investments**




¹GNP implicit price deflators used to convert current to constant dollars
²"Other major investors" includes, United Kingdom, West Germany, Japan, Switzerland, the Netherlands, Canada, and France.

See appendix table 7-13 Science & Engineering Indicators — 1987

ment experiences of some of the United States' most significant technological competitors.

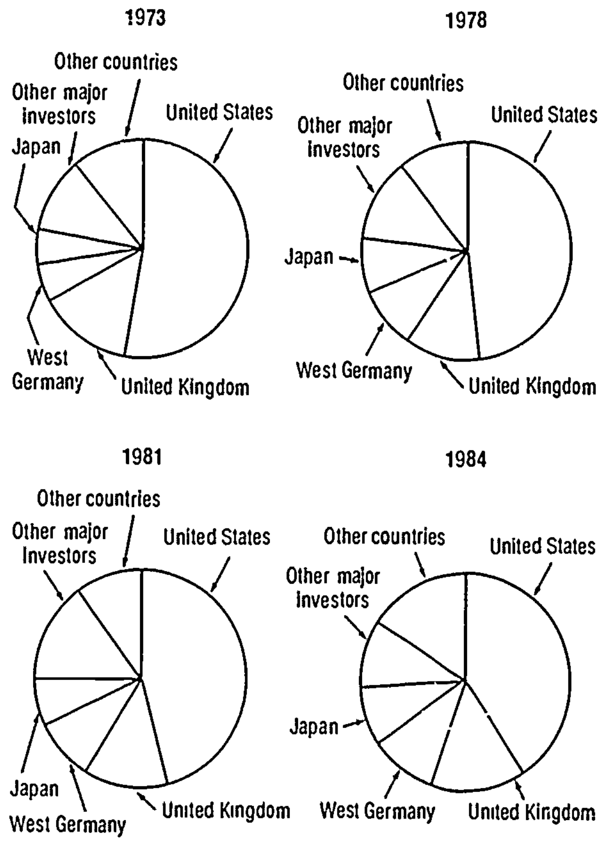
The share of all international direct investment holdings owned by U.S. residents fell from 48 percent in 1973 to 34 percent in 1984; most of this reduction occurred between 1981 and 1984. (See figure 7-11.) The U.K. share was more or less constant, while residents of West Germany increased their share of all holdings from 6 to 9 percent. Japanese holdings grew from 5 to 8 percent, and the shares accounted for by smaller investors rose from 10 to 14 percent.

To some extent, the sharp decline in the U.S. position since 1981 reflects changes in the dollar value of U.S. holdings overseas. Such holdings generally fall when exchange rates climb, as they did during the period in question. However, the decline in the U.S. share dates from before the recent period of a very strong dollar, suggesting that other factors besides exchange rates were present.

In particular, since about one-half of the reduced U.S. share was taken up by the two countries—Japan and West Germany—that are widely assumed to be the strongest technological competitors to the United States, there is reason to conclude that reduced firm competitiveness has contributed to the reduced U.S. presence.

If direct investment positions somewhat reflect the technological positions of a country's firms in the international marketplace, then the substantial growth in direct investment coming from the "other countries" (i.e., those outside the industrialized countries of the OECD) may indicate a broadbased diffusion of technological prowess. This diffusion foreshadows heightened competition in all markets in which U.S. firms operate.

Figure 7-11.
**International direct investment, distribution of ownership**




See appendix table 7-13 Science & Engineering Indicators — 1987



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## REFERENCES


Boretsky, M., "The Threat to U.S. High Technology Industries: Economic and National Security Implications," unpublished report, U.S. Department of Commerce, International Trade Administration, March 1982.

Caves, R.E., *Multinational Enterprise and Economic Analysis* (Cambridge, England: Cambridge University Press, 1982).

Cohen, S., D.J. Teece, L. Tyson, and J. Zysman, "Competitiveness," *Global Competition—The New Reality, Volume III* (Washington, DC: The President's Commission on Industrial Competitiveness, 1984).

Council of Economic Advisers, *Economic Report of the President* (Washington, DC. Government Printing Office, 1985).

Davis, L.A., "Technology Intensity of U.S. Output and Trade," International Trade Administration staff report (Washington, DC: U.S. Department of Commerce, February 1982).

Finan, W.F., P.D. Quick, and K.M. Sandberg, "The U.S. Trade Position in High Technology: 1980-1986," report prepared for the Joint Economic Committee of the U.S. Congress, October 1986.

Hilke, J.C. and P.B. Nelson, *International Competitiveness and the Trade Deficit*, Bureau of Economics Staff Report to the Federal Trade Commission (Washington, DC: Federal Trade Commission, May 1987).

Horst, T., "The Theory of the Multinational Firm: Optimal Behavior under Different Tariff and Tax Rules," *Journal of Political Economy*, Vol. 79, September/October 1971.

Hufbauer. G.C., *Synthetic Materials and the Theory of International Trade* (London. G. Duckworth and Company, 1966).

Kelly, R.K., "Alternative Measures of Technology-Intensive Trade," *Staff Economic Report* (Washington, DC: U.S. Department of Commerce, Office of Economic Research, 1976).

Mansfield, E., A. Romeo, and S. Wagner, "Foreign Trade and U.S. Research and Development," *Review of Economics and Statistics*, Vol. LXI, February 1979.

National Academy of Sciences, *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* (Washington, DC: National Academy Press, 1987).

Shea, M., "U.S. Business Enterprises Acquired or Established by Foreign Direct Investors in 1985," *Survey of Current Business*, Vol. 66, No. 5, May 1986.

Teece, D.J., "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Research Policy*, Vol. 15, No. 6, December 1986a.

Teece, D.J., "Technology Transfer by Multinational Firms. The Resource Cost of International Technology Transfer," *Economic Journal*, June 1977.

Teece, D.J., "Transaction Cost Economics and the Multinational Enterprise, An Assessment," *Journal of Economic Behavior and Organization*, Vol. 7, 1986b.

U.S. Department of Commerce, Bureau of Economic Analysis, "Foreign Direct Investment in the United States: Detail for Position and Balance of Payments Flows, 1986," *Survey of Current Business*, Vol. 67, No. 8, August 1987a.

U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. Direct Investment Abroad: 1982 Benchmark Survey Data* (Washington, DC: Government Printing Office, 1985a).

U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Country and Industry Detail for Position and Balance of Payment Flows, 1984," *Survey of Current Business*, Vol. 65, No. 8, August 1985b.

U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad. Country and Industry Detail for Position and Balance of Payments Flows, 1986," *Survey of Current Business*, Vol. 67, No. 8, August 1987b.

U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates, Preliminary 1984 Estimates," mimeograph, October 1986a.

U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates, Preliminary 1985 Estimates," mimeograph, June 1987b.

U.S. Department of Commerce, International Trade Administration, *International Direct Investment: Global Trends and the U.S. Role* (Washington, DC. Government Printing Office, August 1984).

U.S. Department of Commerce, International Trade Administration, *United States Trade Performance in 1985 and Outlook* (Washington, DC. Government Printing Office, 1986b).

U S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (Washington, DC: Government Printing Office, 1983).

Vernon, R., "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, Vol. 80, May 1966.

# Chapter 8
# Public Attitudes Toward Science and Technology

# Public Attitudes Toward Science and Technology

## HIGHLIGHTS

- *A survey of the adult public in 1985 found that 21 percent are "attentive" to science and technology (S/T),* as defined by their knowledge, interest, and information consumption. This is about twice as many as in the late 1950's. Higher levels of education are the most distinguishing feature of attentive people. In nearly every case, their attitudes toward science and technology are more favorable than the attitudes of others. (See p. 142.)

- *In spite of these levels of attentiveness, few Americans have much understanding of science and technology,* as revealed by their understanding of technical terms and their ability to explain how a familiar technology—the telephone—works. (See p. 143.)

- *Americans are dissatisfied with the teaching of science and mathematics in their schools, and wish to see it improved.* On the other hand, Japanese adults in a 1987 survey expressed a fair level of satisfaction with their science and mathematics education, but doubted that Japanese education is nurturing the individualism and creativity that scientists need. (See pp. 143-145.)

- *The public overwhelmingly believes that science and technology have brought more benefits than harmful results.* However, the number who consider the harmful results greater has increased gradually since 1979. The areas in which science and technology are seen to be most beneficial are mainly medical, technical, and economic Far fewer persons believe that science and technology have benefited world peace or moral values. The Japanese agree about the relative benefits of science and technology in some of these areas, but on the whole their assessment is more negative. (See pp. 147-148.)

- *The public expects significant outcomes from science and technology in the next 25 years or so.* On the positive side, about one-half think it is very likely that cures will be found for cancer and AIDS. There is little expectation of an accidental release of a genetically engineered microbe. On the negative side, more than 40 percent believe there will be another nuclear plant accident like that at Three Mile Island and an accidental release of a toxic chemical that will kill many people. The Japanese public's expectation of positive results is very similar to that of the American public. (See pp. 148-150.)

- *Americans are optimistic about the effect of science and technology on their jobs* The Japanese and, especially, the Americans agree that science and technology have improved general working conditions. While most Americans also agree that science and technology will make work more interesting in the future, the Japanese are almost evenly split on this. (See p. 150.)

- *Americans are optimistic about the effects of automation and the need for it.* The Americans and Japanese largely agree that automation leads to a loss of some jobs. By a small margin, however, Americans believe that the net effect of computers and automation is to increase employment. The Japanese disagree strongly. The Japanese and—especially—the American publics believe that factory automation is necessary to meet foreign competition. (See pp. 150-152.)

- *Scientists generally are highly regarded by the public.* For many years, they have ranked second only to doctors on a list of professionals in whom the American public has confidence. The American, Japanese, and French publics agree that scientists work for the good of humanity. On the other hand, the Americans and the French—but not the Japanese—agree that scientists have a power that makes them dangerous. (See pp. 152-153.)

- *Americans hold many ideas that are outside the scientific mainstream.* Large minorities (between 40 and 50 percent) believe in lucky numbers and unidentified flying objects (UFO's), and that rocket launches have affected the weather. Similar numbers doubt that humans evolved from other animal species. People attentive to science and technology accept UFO's more often than others do. About one-quarter of Americans with graduate degrees believe space activities have affected the weather, believe in lucky numbers, and do not believe in evolution. Japanese attitudes are similar on many of these questions, except for the wider acceptance of evolution by the Japanese. (See pp. 153-155.)

- About 8 percent of the American public say they act on the basis of their astrological forecasts. Support for astrology is strongest among women, the youngest and oldest age groups, and those with the least education. These groups are generally the ones most likely to take views opposed in some way to science and technology. (See pp. 155-156.)

- *Americans believe their country is leading the rest of the world, except for Japan, in science and technology.* In basic science, they believe the United States is ahead of West Germany, Britain, France, and (less clearly) the Soviet Union. By a narrow margin, the United States is considered ahead of Japan. With respect to military technology, the United States is considered to lead all these countries, but by a relatively narrow margin in the case of the Soviet Union. However, in civilian or industrial technology Americans believe Japan is definitely ahead, while the United States leads the other countries. (See pp. 157-158.)

- *The Japanese believe the United States leads in all areas*, but place themselves ahead of the other four countries. In basic science and technology and—to a lesser degree—in technology related to everyday living, they consider the United States to be clearly ahead of them. In industrial technology, they consider the United States to be ahead, but by a very small margin. (See p. 158.)
- *The public believes that science and technology are long-range investments*. About 80 percent believe that the government should support scientific research even when it brings no immediate benefits. (See p. 158.)
- *The public is willing to allow research to go forward in many areas of interest to nonscientists*. This includes medical research involving animals. Support is weaker for research that might lead to new life forms, and there is clear opposition to research designed to lead to new biological or chemical weapons. In those areas where comparison is possible, the Japanese are much more reluctant about allowing research to be pursued. (See pp. 158-160.)
- *Americans are generally satisfied with the level of government regulation* regarding food additives, atomic power plant construction, pharmaceutical manufacture, genetic engineering research, and basic research. Except for basic research, the Japanese wish to see more regulation of all of these, especially food additives. (See pp. 160-161.)
- *In terms of benefits and costs (or risks), the public narrowly is in favor of the space program, genetic engineering, and nuclear power*. About one-half the public favors each one, but there are corresponding minorities of 40-45 percent in opposition. People attentive to science and technology support the space program and genetic engineering research more than the broad public does. In the case of nuclear power, however, "attentives" are about evenly split for and against. (See pp. 161-162.)
- *The Space Shuttle Challenger accident did not diminish public support for the space shuttle program*. In February 1986, immediately after the accident, only a minority thought the explosion was a major setback for the shuttle program. One-half were willing to increase Federal funding for the program if that were needed to get it back on schedule. Nearly everyone believed that manned flights would be resumed and that the shuttle is still an outstanding example of American technology. In June 1986, after the Rogers Commission report, there was more acknowledgment of a major setback and of major design flaws in the shuttle. Support for the program remained high, however. (See pp. 162-163.)
- *The accident at the Soviet nuclear power plant at Chernobyl provoked general concerns about nuclear power*. In June 1986, about a month after the accident, Americans blamed the accident on design errors and operator/manager errors. More than 90 percent stated that there are still major unanswered questions about the safety of nuclear power plants in all countries, and a small majority thought that the risk involved in generating nuclear power should block the construction of new nuclear plants. Still, a small majority believed that the world will primarily depend on nuclear sources of energy 50 years from now, and a large majority believed that science and technology will provide a long-term solution to the energy problem. (See pp. 164-165.)
- *The Challenger and Chernobyl accidents did not erode general confidence in science and technology*. Immediately after the Space Shuttle Challenger accident, public support for the space program increased. Most measures of general public support for science and technology went up. By June 1986, support was still higher than before the accident. The Chernobyl accident did not noticeably affect the public's perception of the risk/benefit balance of nuclear power. (See pp. 163-165.)

Science and technology deeply affect the public through such developments as personal computers, nuclear power, and the space shuttle program. Policymakers must know both if the public understands and accepts these developments, and exactly what the public knows and believes about science and technology in general. This chapter continues and updates earlier *Science Indicators* explorations of such questions. It also introduces some subjects not treated before, such as public acceptance of scientific conclusions, the public's view of the limits of science, and the effect of major technological accidents on attitudes toward science and technology.

Most of this material is taken from a national survey of adults performed for this report in November and December 1985.[1] Supplementary surveys were done in January-February 1986 and June-July 1986, mainly to measure the effects on the public of the technological accidents involving the Challenger Space Shuttle and the Chernobyl nuclear reactor.

For the first time, this chapter also presents an extensive amount of data from surveys performed in other

[1] In November and December, 1985, a national sample of 2,005 adults was interviewed by telephone from the Public Opinion Laboratory at Northern Illinois University. This was 80.2 percent of the original sample of 2,500. With a sample of this size, results are uncertain by ±3 percent or less, at the 95-percent confidence level. With subsamples, the uncertainty will be greater. For more information, see Miller (1988).

countries. In particular, a major survey was performed in Japan in March 1987 using many of the questions in the 1985 U.S. survey.[2] Data from this study provide an unparalleled opportunity to compare public attitudes in the two countries on many important aspects of science and technology policy. At the same time, it should be recognized that the comparison of survey data obtained in widely different cultures using quite different languages presents problems of method that have only begun to be addressed. Hence the conclusions drawn in this chapter about attitudes in different countries should only be taken as the best information available at the present time.

## KNOWLEDGE, INTEREST, AND ATTENTIVENESS REGARDING SCIENCE AND TECHNOLOGY

The public's ability to participate effectively in science- and technology-related public issues depends on having a certain level of relevant knowledge and interest. Efforts have been made to measure and report on such knowledge and interest regarding both particular issues and science and technology in general.

### Attentiveness to Science and Technology

In this chapter (as in previous *Science Indicators* reports), distinctions are made among that portion of the public "attentive" to science and technology, an "interested" or "potentially attentive" group, and the remainder of the public. These three groups were identified by asking all respondents a set of questions about their knowledge of science and technology, their interest in science and technology, and their habits of information acquisition. Those who scored high on all three measures were considered to be *attentive*.[3] These are the members of the public most likely to get involved when an issue related to science and technology becomes a public controversy. These persons may, for example, contact legislators or opinion leaders or write letters to newspaper and magazine editors. The attitudes of this group of citizens are of special importance not only because of their likely participation, but also because they have presumably thought more about the science- and technology-related issue than have other citizens, and therefore are more likely to express stable attitudes in which they have confidence when asked questions about science and technology.

A second group of respondents is defined as *interested* rather than attentive because it meets the interest condition but not the knowledge and information acquisition conditions for being recognized as attentive. Members of this group are considered potentially attentive because they presumably would be willing to acquire information and become attentive under certain conditions.[4] This is thus an especially suitable group to which to address science and technology information programs.

The third group, *the remaining public*, is the group most likely to report opinions that are easily changed and that these respondents themselves do not consider well grounded. However, this group's views about science and technology are also important—not only because this group is so large, but also because under special circumstances its members too may be stirred into action by some situation that affects them directly.

Science and technology is only one of the many fields to which an intelligent and busy person can pay attention. This model therefore does not imply that everyone ought to be attentive to science and technology, that there is something wrong with not being attentive, or that the professional community should address itself to only one group. Rather, this way of dividing the public identifies three groups with different information needs; groups whose expressed attitudes are often different. In this chapter, the responses of all three groups frequently will be presented so that their attitudes can be compared.

About 20 percent of the U.S. adult public qualifies as attentive to science and technology. (See table 8-1.) While the level of attentiveness has fluctuated around this figure since 1979, it was only one-half this high in 1957. This suggests a continuing growth in the public's awareness of science and technology. College students, who were separately surveyed, also showed high levels of attentiveness; in 1983, 25 percent were attentive. In 1985, both the college students and the broader adult group showed unexplained drops in attentiveness from their 1983 levels.[5]

Citizens attentive to science and technology are found in all demographic groups. There is no significant difference in the attentiveness of different age groups. Men, however, are more likely to be attentive than are women. (See appendix table 8-1.) The most significant predictor of attentiveness to science and technology is education. Science and technology appear to require higher levels of education for people to feel comfortable and informed about them. College students in 1985 showed slightly lower levels of attentiveness and interest than the corresponding portion of the adult public, those with only a high school education.

[2]The survey was sponsored by the Public Relations Office of the Prime Minister's Secretariat. Personal interviewing was done in March 1987 with 2,334 respondents out of an original sample of 3,000, for a response rate of 77.8 percent. For a complete report of this survey, see Office of the Prime Minister of Japan, Public Relations Office (1988). This report is being issued simultaneously with *Science & Engineering Indicators—1987*, and is the source for all Japanese data discussed in this chapter.

[3]Specifically, respondents were regarded as attentive if they reported being very interested and very well-informed about either new scientific discoveries or the use of new inventions and technologies. In addition, respondents had to have a pattern of sustained information acquisition through the regular use of two or more news sources. Such people are considered most likely to keep up with science- and technology-related issues. In measuring attentiveness, the respondents' self-reported knowledge was used instead of testing their actual knowledge. Since attentiveness serves as an indicator of willingness to become involved politically, self-perceived knowledge is more important for this purpose than actual knowledge. See Miller (1983a).

[4]For more information on this model, see Miller (1983a).

[5]For a study of college student attitudes toward science and technology and other subjects in 1985, see Miller (198

Table 8-1. Percent of American public attentive[1] to and interested in science and technology

| | Adults | | | | | College students | |
|---|---|---|---|---|---|---|---|
| | 1957 | 1979 | 1981 | 1983 | 1985 | 1983 | 1985 |
| Attentive ........... | 10 | 19 | 20 | 24 | 21 | 25 | 16 |
| Interested .......... | 12 | 21 | 19 | 28 | 26 | 22 | 23 |
| N = | 1,919 | 1,635 | 3,195 | 1,630 | 2,005 | 2,011 | 2,373 |

[1] Interested in and informed about science and technology, and regularly acquiring information.

Note: N in each case is the number of respondents.

See appendix table 8-1. See also Miller (1986).

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## Knowledge of Scientific and Technical Terms

Part of the public's scientific and technological sophistication is its ability to recognize and understand certain S/T terms. Respondents were given a list of five science- and technology-related terms that someone might encounter through newspapers, magazines, or television, and were asked if they had a "clear understanding," a "general sense," or "little understanding" of these terms. (See table 8-2.) The terms chosen were relatively familiar ones and together covered a broad range of fields. Almost 30 percent reported that they had a clear understanding of what "radiation" is and what a "molecule" is. Most respondents reported little understanding of "DNA" or "GNP" and one-half had little understanding of "computer software." The highest levels reporting a clear understanding of these items were among attentives[6] and, correspondingly, among males and those with higher levels of education.

Another dimension of scientific knowledge is having some conception of how science and technology work. Respondents thus were asked what it means to study something scientifically. (See table 8-2.) This is a point that may come up when commercial advertising suggests that some product has been tested scientifically, or when results are published from a new study of the effect of diet on susceptibility to a disease. Even among the attentive public, only a minority report a clear understanding of what scientific study is. About one-half report that they have a general sense of what it is.[7]

There was no similar question by which to gauge general comprehension of technology. Instead a very common technology—the telephone—was selected, and respondents were asked whether they understood its operation. Only 1 in 12 Americans claims to have a clear understanding of how a telephone works. (See table 8-2.) About one-half of the public claims a general sense of how telephones work, while one-third claims little understanding. Appendix table 8-2 shows the response of different demographic groups.

To determine the accuracy of this self-reported level of understanding, respondents were sometimes asked to state in their own words what they understood by a particular item.[8] There were far fewer who actually understood the items than had previously claimed a clear understanding of them. (See table 8-3.) Attentives did better than others, but still did not show high levels of understanding. Demographic differences are shown in appendix table 8-3. Correct responses are strongly related to higher levels of education. While only a small minority answered it correctly, the question about telephones brings out the strongest difference between the sexes and among age groups;[9] the question about scientific study shows no differences with respect to sex.

The Japanese survey also asked whether respondents understood certain terms, but did not attempt to test the reported understanding. Three of the terms—GNP, computer software, and DNA—were the same as those used in the U.S. survey. While absolute numbers in the two surveys cannot be compared on this question, it is noteworthy that the Japanese responses on these three terms fell in the same order as did the American responses, with GNP being most familiar to both Japanese and American respondents and DNA least familiar. (See table 8-2 and appendix table 8-4.)

## Attitudes Toward Science and Engineering Education

The public expresses widespread dissatisfaction regarding the teaching of science and mathematics in American schools. (See table 8-4.) Correspondingly, there is a wish to see science, and especially mathematics, taught in every year of high school.[10]

The American question was worded in negative terms ("The quality of science and mathematics education in American schools is inadequate") and evoked a high level of negative sentiment about American education. Japanese respondents were asked a slightly different ques-

[6] It should be noted that these items are part of the knowledge condition that enters into the definition of attentiveness.

[7] Miller (1988).

[8] The question was not asked of those who had said they had little understanding of the item.

[9] Here and elsewhere in this chapter, varying responses among age groups seem to be due to differences in education. Age as such does not seem to explain much of the response. See Miller (1988).

[10] See also chapter 1, "Precollege Science and Mathematics Education."

**Table 8-2. Reported understanding of various aspects of science and technology, by attentiveness: 1985**

| Aspect | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent claiming clear understanding | | | |
| Radiation | 29 | 45 | 31 | 21 |
| Molecule | 27 | 45 | 33 | 18 |
| GNP | 23 | 41 | 24 | 16 |
| Computer software | 20 | 34 | 20 | 15 |
| DNA | 14 | 24 | 16 | 9 |
| Scientific study | 29 | 42 | 31 | 24 |
| How a telephone works | 18 | 24 | 20 | 14 |
| N = | 2,005 | 417 | 517 | 1,071 |

"Radiation: When you read or hear the term 'radiation'; do you have a clear understanding of what it means, a general sense of what it means or little understanding of what it means?"

See appendix table 8-2. Science & Engineering Indicators—1987

**Table 8-3. Actual understanding of various aspects of science and technology, by attentiveness: 1985**

| Aspect | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent responding correctly[1] | | | |
| Molecule | 10 | 15 | 10 | 7 |
| Scientific study | 12 | 16 | 12 | 12 |
| How a telephone works | 8 | 13 | 7 | 6 |
| N = | 2,005 | 417 | 517 | 1,071 |

"In your own words, could you tell me what a molecule is?"

[1] Question was asked only of those who previously had stated they had either a "clear understanding" or a "general sense" of this aspect. Percentages are based on total sample. Responses were coded at the Public Opinion Laboratory, with tests of intercoder reliability.

See appendix table 8-3. Science & Engineering Indicators—1987

**Table 8-4. Attitudes toward science and mathematics education in the United States: 1985**

| | Agree | Disagree | No opinion |
|---|---|---|---|
| | Percent | | |
| The quality of science and mathematics education in American schools is inadequate | 63 | 29 | 8 |
| Every high school student in the United States should be required to take a science course every year | 69 | 28 | 3 |
| Every high school student in the United States should be required to take a math course every year | 87 | 12 | 1 |

SOURCE: Jon D.Miller (1988) Science & Engineering Indicators—1987

tion: whether the science and mathematics coursework in their schools is serving the purpose of nurturing the students' awareness of science. Forty-six percent of the Japanese surveyed agreed, 35 percent disagreed, and 20 percent had no opinion.

Many writers have suggested that Japan will not be able to sustain its technological growth if it cannot create its own basic scientific and technological knowledge—knowledge that previously could be borrowed from other countries. This will require a creativity and en-

Table 8-5. Reported use of public information sources: 1985

| Source and frequency (times per year) | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Watches science television: | | | | |
| Never | 29 | 16 | 25 | 37 |
| Occasionally | 51 | 54 | 54 | 49 |
| Regularly | 20 | 31 | 21 | 15 |
| Visits a public library: | | | | |
| None | 33 | 22 | 29 | 39 |
| One or two | 16 | 17 | 18 | 14 |
| Three or more | 51 | 61 | 53 | 47 |
| Visits a zoo or aquarium: | | | | |
| None | 52 | 44 | 53 | 54 |
| One or two | 37 | 42 | 37 | 36 |
| Three or more | 11 | 14 | 10 | 10 |
| Visits a science and technology or natural history museum: | | | | |
| None | 62 | 47 | 62 | 68 |
| One or two | 27 | 35 | 27 | 24 |
| Three or more | 11 | 18 | 11 | 8 |
| Visits an art museum: | | | | |
| None | 69 | 56 | 68 | 74 |
| One or two | 23 | 31 | 24 | 20 |
| Three or more | 8 | 13 | 9 | 6 |
| Reads science magazines: | | | | |
| Never | 84 | 68 | 84 | 90 |
| Occasionally | 6 | 7 | 9 | 4 |
| Regularly | 10 | 26 | 7 | 6 |
| N = | 2,005 | 417 | 517 | 1,071 |

SOURCE: Jon D. Miller (1988)

See appendix table 8-5.

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trepreneurship that some allege does not exist in Japan. Japanese respondents thus were also asked if "Compared with other countries, Japan is very meager in training individualists and creative scientists." This question too was negatively worded, and it found 53 percent of respondents agreeing (12 percent "completely agreed"), 27 percent disagreeing, and 19 percent uncertain. Agreement was highest among respondents with university and college degrees.

## PERSONAL ACTIVITIES INVOLVING SCIENCE AND TECHNOLOGY

In spite of the limitations in the public's knowledge, there still are various way in which many people deal with science and technology on a daily basis in their home life, their work, and even in their leisure-time activities. Data are available for some of these activities, and they help to show the extent to which various groups within the public take advantage of the opportunity to learn about or use science and technology.

### Consumption of Information

Adult Americans report a moderately high level of exposure to publicly available sources of science and technology information. (See table 8-5.) All of the activities listed for these sources are primarily leisure-time activities, and can be arranged roughly in order of difficulty. Thus, reading science magazines is the activity with the fewest participants,[11] since special effort must be made to acquire the magazines, and some level of sophistication is required to read them. Most people, on the other hand, can watch and enjoy an occasional National Geographic Special very easily; therefore, there is a low percentage of the public that does not watch science-

[11]The questions on science magazines and science television are not strictly comparable with the others, since the list of responses is different. However, the numbers who never read science magazines or watch science television can be compared with the numbers who do the other activities 0 times per year.

related television at all. In between are visits to zoos, aquariums, and museums. Some effort is required to do these things, but—especially in the case of zoos and aquariums—there is little that is difficult to understand.

To help interpret the frequency of use for these information sources, the frequency of use for two nonscientific or general information sources—art museums and public libraries—is also shown. Art museums are slightly less popular than science and technology museums. Public libraries, on the other hand, have the highest number of users who visit three or more times per year. Next to television, libraries are the most widely accessible of the sources listed; they also provide the broadest range of scientific and other information.

Predictably, attentives take part in these information acquisition activities more than do other members of the public.[12] Substantial differences between the attentive public amd the remaining public also exist for watching science television and visiting science and technology museums. Attentives are also heavier users of public libraries and art museums. This suggests that attentives are heavier users of information and culture sources in general, apparently because of their higher level of education.

If one looks at demographic characteristics, these patterns of use of information sources are more understandable. (See appendix table 8-5.) Attendance at museums, zoos, and aquariums seems to decrease sharply with increasing age; clearly, these are avenues more suitable for imparting information to younger adults. Since many adults visit such places mainly to bring their young children, this may help to explain the lower attendance by older adults. Magazine use decreases at both ends of the age spectrum, while use of science-related television increases with age. Education is a strong influence on the level of use of any type of information source. Since the average educational level is lower for the youngest and the oldest Americans, education may help to explain these differences in participation by age.

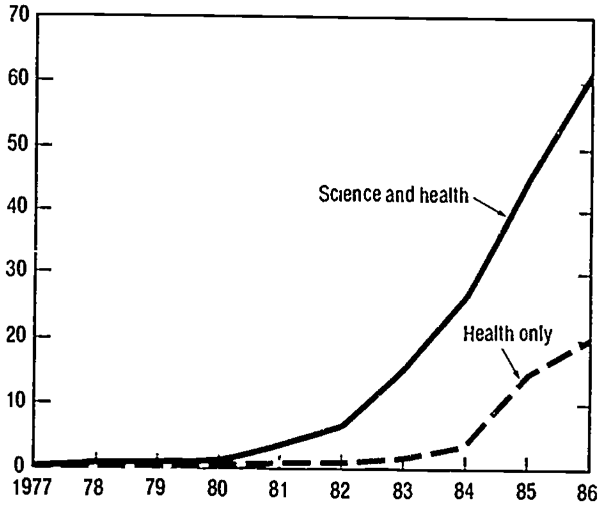
Another major source of information is newspapers. There has been considerable expansion in the number of weekly science sections appearing in American newspapers, particularly from 1984 to 1986. (See figure 8-1.) While many of these sections are exclusively devoted to health and fitness, there also has been a considerable growth in science sections presenting a broader range of materials. This implies a growing public interest in scientific subjects of all kinds and an increasing public consumption of such information, in part because more and more consumer goods are products of science and technology. This interest is further evidenced by the fact that there were about 81 daily newspapers with a science page in early 1987.[13]

## Use of Computers

The computer—a technological product that many Americans have learned to use in recent years—is an

Figure 8-1.

**Weekly science and health sections in U.S. daily newspapers**




See appendix table 8-6.

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especially interesting illustration of the growing effect of science and technology on the public. Many commercial products, from toys to automobiles, contain built-in computers. Business use of computers has been developing over several decades and is now widespread. About one-quarter of adults reported that they use computers at work. (See table 8-6.) (Since no specific kind of computer was mentioned, respondents presumably were referring to a broad range of devices such as computerized cash registers and word processors in addition to more conventional computers.[14]) Those who do use computers at work spend the equivalent of almost 2 working days per week at their terminals on average. While attentives are more likely to use computers at work than others are, those who have computers at work use them about as much whether they are attentives or not.

Home computers have been common for a shorter time and are not as widespread. Still, 15 percent of Americans report having a computer in their homes, up from 9 percent in 1983.[15] Home computers are used fewer hours per week than are business computers. (See table 8-6.)

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[12]In the case of reading science magazines this is expected, since reading such magazines enters into the definition of attentiveness.

[13]*Science* (1987), p. 429.

[14]The estimated level of computer use at work varies widely from one survey to another, probably because of the wide variety of devices that can be considered computers. A survey of computer use in industrial R&D organizations in 1984 found that an average of 42 percent of scientists and engineers in those organizations use them. Forty-two percent of senior managers had their own terminals, while fewer lower-level managers did. See Rossini and Porter (1985).

[15]Miller (1983b). Another study found that 13 percent of adults, 26 percent of children aged 12-17, 22 percent of those 6-11, and 17 percent of those 2-5 had access to a home computer in 1985. See Ancarrow (1987), table 1. For more information, also see chapter 1, "Precollege Science and Mathematics Education."

**Table 8-6. Reported use of a computer at work and at home: 1985**

| Activity | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| Use computer at work and at home (percent) | 6 | 12 | 5 | 4 |
| Average hours per week at work | 13.9 | 12.7 | 14.6 | 14.9 |
| Average hours per week at home | 5.1 | 5.3 | 4.7 | 5.1 |
| Use computer at work only (percent) | 19 | 23 | 22 | 16 |
| Average hours per week at work | 14.8 | 15.3 | 14.5 | 14.7 |
| Use computer at home only (percent) | 9 | 11 | 8 | 9 |
| Average hours per week at home | 1.8 | 1.8 | 3.0 | 1.2 |
| Do not use computer (percent) | 66 | 54 | 65 | 71 |
| N = | 2,005 | 417 | 517 | 1,071 |

"Do you presently own a home computer?"

"Do you use a computer in your work?"

See appendix table 8-7.

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Owners of home computers spend more time on them if they also have computers at work. Attentives show higher levels of home computer ownership than the rest of the public. However, the group which has only home computers and which uses them the most are not attentives, but the interested public.

In demographic terms, computer use is positively associated with higher levels of education. (See appendix table 8-7.) Interestingly, however, graduates of associate's degree programs have an especially high level of home computer use. Many of these people are technicians, computer operators, or computer programmers. Home computers are most frequently found in the 35-44 age group, while younger people are generally more likely to use a computer at work.

The Japanese respondents were also asked about their use of computers. While about 25 percent of Americans reported using a computer at work, only 12 percent of Japanese did so. This appears to be a significant difference.[16] In the case of managerial and professional workers, 51 percent reported using computers at work Among clerical and service workers this figure was 42 percent. Nine percent of the Japanese respondents reported owning home computers, the comparable figure for Americans was about 12 percent.[17]

## PERCEIVED RESULTS OF SCIENCE AND TECHNOLOGY

The public has various opportunities to think about scientific and technological developments and to judge how these developments are related to their own lives. Television broadcasts and newspaper articles announce new discoveries; the present and potential impacts of these discoveries on society are discussed and explored in magazine articles, sermons, personal conversations, and in many other ways. It is thus of interest to ask what judgments the public has formed about the advantages and disadvantages of science and technology, and about the changes they are likely to bring in the future. More specifically, since science and technology are known to have significant impacts on the content of work and levels of employment, it is of special interest to gauge the public's feelings about these impacts.

### Benefits versus Harms from Scientific Research

The public overwhelmingly believes that scientific research has brought more benefits than harms. (See table 8-7.) Only 19 percent believe the harms exceed the benefits. This is up from 11 percent in 1979, and 14 percent in 1981,[18] however, indicating some growth in the negative perception of science and technology over the last several years. Those with a college education are most likely to say that the benefits substantially exceed the harms; correspondingly, those who consider harms greater than benefits tend to have lower levels of education. (See appendix table 8-8.) There is also a discernible gender difference, wi h more men than women maintaining th the benefits are substantially greater than the harms. A 55-percent majority of attentives agree that the benefits

[16]There are some differences in the definition of a computer For example, the Japanese survey excluded word processors, and the American survey—in the case of home computers—excluded those primarily used for entertainment. The 1985 British survey found that 6 percent of respondents used typewriters with an electronic memory, 5 percent used computer-controlled machine tools, 8 percent used computer-aided design/computer-aided manufacturing (CAD/CAM) equipment, and 13 percent used other computers or terminals at work, at school, or at college. See Market & Opinion Research International Limited (MORI) (1985), p. 11.

[17] This number omits the American home computers that are primarily used for word processing, in order to better match the Japanese definition of computers. In Great Britain, 18 percent reported using a home computer in 1985. See MORI (1985), p. 22.

[18]See National Science Board (1981), p. 161, and National Science Board (1983), p. 147. Data from other years are shown in National Science Board (1985), p. 153 They are not comparable with the data shown here because the question asked in these years offered three possible answers, rather than two as here.

**Table 8-7. Public assessment of beneficial versus harmful results of scientific research**

| Assessment | 1979 | 1981 | 1985 |
|---|---|---|---|
| | Percent | | |
| Balance strongly favors beneficial results | 46 | 46 | 44 |
| Balance only slightly favors beneficial results | 24 | 28 | 24 |
| About equal¹ | 13 | 11 | 4 |
| Balance only slightly favors harmful results | 7 | 10 | 13 |
| Balance strongly favors harmful results | 4 | 4 | 6 |
| Don't know | 6 | 1 | 8 |
| N = | 1,635 | 1,540 | 2,005 |

"People have frequently noted that scientific research has produced both beneficial and harmful consequences Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or that the harmful results of scientific research have outweighed its benefits?"

¹ Volunteered by respondent.

See appendix table 8-8. Science & Engineering Indicators—1987

are substantially greater than the harms. Fewer members of the interested public believe this, and still fewer members of the remaining public, but this view is still the one expressed most frequently by all three groups.

In Japan, the 1987 survey included the question "Science and technology have both their pluses and minuses, but from your standpoint which do you think are greater?" Fifty-four percent thought the pluses were greater, 8 percent thought the minuses were greater, and 29 percent considered them equal (9 percent had no opinion). Though the questions were not quite the same, it is notable that the balance of positive over negative responses was greater in Japan than in the United States (cf. table 8-7).[19]

These responses can be understood better by examining the individual areas of life that research is thought to have hurt or benefited. Science and technology are thought to have been especially beneficial in technological and economic areas, namely the standard of living, public health, and working conditions. (See table 8-8 ) On the other hand, large minorities feel that science and technology have had negative effects on world peace and, especially, on moral values. Thus, cultural and military aspects of science and technology are viewed more negatively than are economic and health aspects. The individual's enjoyment of life involves both economic and more personal considerations, thus, the "positive effect" responses in this case fall between those received for the technological-economic items and the personal and social items.

Four of these effects were also explored i  the Japanese survey.[20] In general, the Japanese much  e frequently answered "don't know" or "neither" when asked about the effects of science and technology in these areas. (See table 8-8.) A high frequency of "don't know" or neutral responses is commonly observed in Japanese opinion surveys, and seems to be a cultural characteristic.[21] This should be taken into account when interpreting all survey data involving Japan and other countries. While Japanese respondents in this survey agreed with Americans that the most positive effect of science and technology has been on the standard of living, they were much less willing than Americans to accept the idea that science and technology have improved working conditions. Moreover, the Japanese were even less inclined than Americans to accept that science and technology improve morality.[22]

Another view of the public's perception of benefits and risks is obtained by looking at the responses to the same question in a variety of countries. (See figure O-33 in Overview.) In 1981, a coordinated set of surveys was done in 17 countries asking whether scientific advances will help or harm mankind in the long run.[23] Among the industrialized countries, the United States showed the highest level of positive response. British, Spanish, Canadian, and Australian respondents also gave a high proportion of positive replies. The Netherlands was the only country giving more negative than positive replies. In Japan—and to a lesser extent in Belgium, Denmark, and West Germany—many respondents were unwilling to say that mankind will be either helped or hurt, opting instead for the answer "both." (See appendix table 8-9.) In the case of Japan, this may again reflect the general tendency to give neutral responses. The effects these opinions have had on public science and technology policies in these countries would make a useful subject for further study.

## Expectation of Future Scientific and Technological Developments

Respondents were also asked how likely they thought it is that science and technology will produce certain

[19]The 1985 British survey asked "Some people believe that man has gone too far in tampering with nature through scientific enquiry Others say this kind of scientific enquiry has brought great benefits to man and should be encouraged Which comes closest to your own view?" Thirty percent replied that science has gone too far, 53 percent that it has brought great benefits, 10 percent said "neither," and 7 percent replied "don't know" While the wording may have encouraged negative responses, there was a preponderant support for science See MORI (1985).

[20]The Japanese question was "Do you think that the following factors have been bettered or worsened by scientific and technological developments? Or do you think they have been unchanged?" The U.S. question was "Now, I want to read you a short list of areas and for each one, please tell me if you think that science and technology have had a positive effect, a negative effect, or neither kind of effect."

[21]See Kuroda, Hayashi, and Suzuki (1986).

[22]In 1982, 17 percent of respondents to a French survey said that scientific and technological development have had more favorable effects on the moral sense, 42 percent said the effects were more unfavorable, and 24 percent said neither. See Bon and Boy (1984b), p. 47. This attitude appears closer to the American than to the Japanese response.

[23]For the entire list of countries surveyed, see appendix table 8-9. The Canadian part of the survey was actually done in 1982, while the Kuwaiti, Lebanese, and Australian parts were done in 1983. Since year-to-year changes tend not to be large, the opinions shown for these years should be close to current opinions. Because of differences in question wording and survey administration, the data shown for the United States on figure 8-2 are not strictly comparable with those shown for the United States in 1981 on table 8-7.

**Table 8-8. Impact of science and technology on other areas of life: American, Japanese, and French responses**

| Area and country | Positive effect | Neither | Negative effect | Don't know |
|---|---|---|---|---|
| | Percent | | | |
| Our standard of living: | | | | |
| United States | 84 | 6 | 8 | 2 |
| Japan | 73 | 18 | 3 | 5 |
| France | 79 | 10 | 7 | 5 |
| The public health: | | | | |
| United States | 83 | 4 | 12 | 2 |
| Japan | NA | NA | NA | NA |
| France | 77 | 7 | 13 | 3 |
| General working conditions: | | | | |
| United States | 79 | 8 | 11 | 2 |
| Japan | 40 | 29 | 21 | 11 |
| France | 76 | 6 | 13 | 4 |
| The individual's enjoyment of life: | | | | |
| United States | 69 | 12 | 15 | 4 |
| Japan | 46 | 35 | 8 | 12 |
| France[1] | 59 | 12 | 21 | 8 |
| World peace: | | | | |
| United States | 42 | 18 | 33 | 7 |
| Japan | NA | NA | NA | NA |
| France | 23 | 23 | 41 | 14 |
| People's moral values: | | | | |
| United States | 25 | 28 | 41 | 6 |
| Japan | 5 | 38 | 42 | 15 |
| France | 17 | 24 | 42 | 18 |

[1] In France, the item was "the structure of daily life."

Note: N = 2,005 (United States, 1985)
N = 2,334 (Japan, 1987)
N = 1,515 (France, 1982)

SOURCES: Japan: Office of the Prime Minister of Japan (1988); United States. Jon D. Miller (1988); France. Frederick Bon and Daniel Boy (1984).

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specific outcomes in the next 25 years or so. It is evident that the public expects continued medical developments. about one-half of the public thinks it very likely that cancer and AIDS will be curable in the next generation. (See table 8-9.) A half of the public also thinks there will be no wars in space in the next 25 years, and belief that such a conflict is unlikely to occur actually rose significantly from 1983 to 1985. On the other hand, nearly half of the public considers such wars at least possible.

Large minorities consider it very likely that there will be an accidental release of a toxic chemical causing numerous deaths and another nuclear accident such as the one at Three Mile Island.[31] This question was asked after the major chemical accident in Bhopal, india, but before the nuclear accident in the Soviet Union at Chernobyl.

Opinion is almost evenly split on the accidental release of a genetically engineered microbe and on the items related to space technology. While attentives are somewhat more optimistic about space-related and medical achievements than is the rest of the public, in many areas their expectations are virtually the same as those held by others. (See appendix table 8-10.) For example, there is no significant difference between attentives and others in their expectation of chemical and nuclear accidents.

The Japanese survey also included a question about expectations for the next 25 years. (See appendix table 8-11.) The question included four possible outcomes that were the same as outcomes listed in the U.S. survey. It is notable that the Japanese ordered the likelihoods of these four outcomes in just the way that the American respondents did. The outcome considered most likely was a cancer cure, followed by a cure for AIDS, a method for processing atomic wastes, and a manned Mars landing.

[31] In the 1985 British survey, respondents were asked separately about a list of things that will and will not result from the application of science and technology over the next few years. Twenty six percent believed that problems associated with nuclear waste will be solved, 39 percent thought they will not; 36 percent did not say either. Thirty-seven percent said there will be a major accident at a nuclear power station, 22 percent said there will not, 41 percent said neither. See MORI (1985), p. 8.

**Table 8-9. Public expectations concerning future outcomes**

| Outcome | Year asked | Very likely | Possible | Not at all likely | Don't know | N |
|---|---|---|---|---|---|---|
| | | Percent | | | | |
| A cure for the common forms of cancer .................... | 1979 | 46 | 44 | 8 | 2 | 1,635 |
| | 1983 | 57 | 36 | 6 | 1 | 1,630 |
| | 1985 | 55 | 37 | 6 | 2 | 2,005 |
| A cure for the disease AIDS ... | 1985 | 49 | 38 | 9 | 4 | 2,005 |
| Another nuclear power plant accident like Three Mile Island ... | 1985 | 46 | 41 | 9 | 3 | 2,005 |
| The accidental release in the United States of a toxic chemical that will result in numerous deaths .................... | 1985 | 42 | 42 | 12 | 4 | 2,005 |
| A safe method for the long-term storage or disposal of waste products from nuclear power plants ..................... | 1983 | 29 | 41 | 26 | 4 | 1,630 |
| | 1985 | 36 | 42 | 18 | 4 | 2,005 |
| The placement of a scientific or mining colony on the moon .. | 1985 | 32 | 39 | 25 | 4 | 2,005 |
| The development of genetically engineered bacteria to eat or destroy toxic chemicals ...... | 1985 | 32 | 43 | 17 | 8 | 2,005 |
| The landing of a manned mission on Mars ............... ... | 1985 | 27 | 41 | 29 | 3 | 2,005 |
| The accidental release of a genetically engineered microbe into the environment ........... | 1985 | 17 | 50 | 20 | 13 | 2,005 |
| A war in space ............... | 1983 | 26 | 36 | 36 | 2 | 1,630 |
| | 1985 | 12 | 34 | 50 | 4 | 2,005 |

"Do you think that it is very likely, possible but not too likely, or not at all likely that this result will occur in the next 25 years?"

SOURCES: Miller, Prewitt, Pearson (1980); Miller (1982, 1984, 1988).

See appendix table 8-10.

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### Effect of Science and Technology on Work and Employment Levels

Employment is one of the most personal effects that science and technology has on the lives of the public. New technological developments have affected the way in which work is done and the training needed for a given job. In the aggregate, they help to determine how many employees are needed in a given field and which are the fields in which employment opportunities are available. Concerns about the effects of "automation" and/or "robots" on the nature and availability of work have been expressed widely in many countries for many years. Data capturing these concerns are available for the United States and Japan. (See table 8-10.)

There seems to be agreement between the two countries that science and technology have improved working conditions. (See table 8-10, question A.) This idea seems to be more widely accepted in the United States. The Japanese are optimistic about science and technology making work more interesting in the future, and Americans are more optimistic still. (See table 8-10, question B.)

More vital than the *nature* of work is whether one will have a job at all. Respondents in the United States and Japan agree that automation will lead to a loss of jobs. (See table 8-11, question A.[15]) On the other hand, Americans are split on whether technological developments are a main reason for high unemployment, with 48 percent accepting this and 45 percent disagreeing.[16]

Although it is agreed that computers and automation will eliminate some jobs, it is widely held that they create

[15] In the U.S., the question was whether factory automation will put many hundreds of thousands of people out of work in this country in the next 5 years. The Japanese question was "If robots and computers become widespread, many tens of thousands of people will lose their jobs."

[16] Miller (1988).

## Table 8-10. U.S. and Japanese attitudes about the effects of science and technology on working conditions

| | Beneficial | Neither | Harmful | Don't know |
|---|---|---|---|---|
| | Percent | | | |
| A. Effect science and technology have had on general working conditions: | | | | |
| United States | 79 | 8 | 11 | 2 |
| Japan | 40 | 29 | 21 | 11 |

| B. Science and technology will make work more interesting: | Agree | Disagree | Don't know |
|---|---|---|---|
| | Percent | | |
| United States | 71 | 24 | 5 |
| Japan | 47 | 37 | 17 |

Note: N (United States, 1985) = 2,005
N (Japan, 1987) = 2,334

SOURCES: United States: Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

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## Table 8-11. U.S. and Japanese attitudes about the effects of robots and automation in employment

| Country | Agree | Disagree | Don't know |
|---|---|---|---|
| | Percent | | |
| A. Automation will put many factory employees out of work: | | | |
| United States | 73 | 25 | 3 |
| Japan | 63 | 27 | 10 |
| B. Computers and automation will create more jobs than they will eliminate: | | | |
| United States | 48 | 44 | 3 |
| Japan | 13 | 73 | 14 |
| C. Automation is necessary to meet foreign competition: | | | |
| United States | 75 | 21 | 5 |
| Japan | 51 | 27 | 21 |

[1] Respondents were offered a list and asked which things will happen, and then separately which things will not. This percent of respondents did not mention this item either time.

Note: N (United States, 1985) = 2,005
N (Japan, 1987) = 2,334

SOURCE: United States: Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

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others, in both technical fields and service industries. The net effect thus may still be an increase in employment. However, respondents are not all convinced of this. (See table 8-11, question B.[77]) The Americans are about evenly divided for and against this idea, and the Japanese are distinctly skeptical.

Even if it fails to generate more employment, many writers suggest that automation is necessary to meet competition from other countries that do automate their factories. The American and Japanese publics appear to accept this position. (See table 8-11, question C.[78]) The Americans seem to show a higher level of belief in the need for automation, but support is also high in Japan. Part of the explanation for Japanese support of automation may be seen in their response to another question.

[77]The American question was "On balance, computers and factory automation will create more jobs than they will eliminate." In Japan, it was "The number of jobs that will increase as a result of the spread of robots and computers is greater than the number that will decrease as a result of their spread." A French survey in 1982 asked whether "In the long run, technological progress creates more employment than it abolishes." Forty-two percent agreed, 47 percent disagreed, and 10 percent did not know. This resembles the American response. See Boy and Boy (1984b), p. 42.

[78]The U.S. question was "If we don't automate our factories, American products will be too expensive to compete successfully against products made in automated factories in Japan and Europe." In Japan, it was "If robots and computers do not become widespread, we will not be able to win in the price competition with foreign products."



1C.

The survey noted that recently, newly industrializing countries such as Korea and Taiwan have been making spectacular progress in science and technology. It then asked respondents whether they considered this a threat to Japan or not. A 57-percent majority agreed, while 27 percent disagreed, and 16 percent did not reply. Agreement was especially high among those who believed that automation is necessary in order to meet foreign competition.

The British also believe that science and technology will improve the competitiveness of their industry, but it is not clear that they consider the price worth paying. For example, they do not believe that science and technology will create more jobs than they will destroy.[29] While 84 percent believe that new technology is essential for their country's prosperity,[30] the British are about evenly split on the desirability of robots in industry.[31] They believe more than do Americans that because of science and technology the rich get richer and the poor poorer.[32] Further, they believe much less than do Americans that because of science and technology there will be more opportunities for the next generation.[33]

## PUBLIC ACCEPTANCE OF SCIENCE AND TECHNOLOGY

Science and technology are part of the general culture and, as such, compete with other social institutions for public prestige and acceptance. It is therefore of interest to ask whether the public trusts and admires scientists, and would be likely to support their work and endorse their testimony on public issues. It is also of interest to ask whether the public wishes or is able to think scientifically. Scientific thinking is only one of several available modes of thinking, and the scientific community especially should be aware of the extent to which such thinking has diffused among the public. Finally, the public's view of American science and technology in comparison with the efforts of other countries is another aspect of the prestige of U.S. science and technology.

[29]See MORI (1985), p. 20. Forty-seven percent believed that the competitiveness of British industry will improve as a result of the application of science and technology, while 14 percent believed it will not. However, only 19 percent believed that more jobs will be created than destroyed by this application, while 15 percent believed they will not

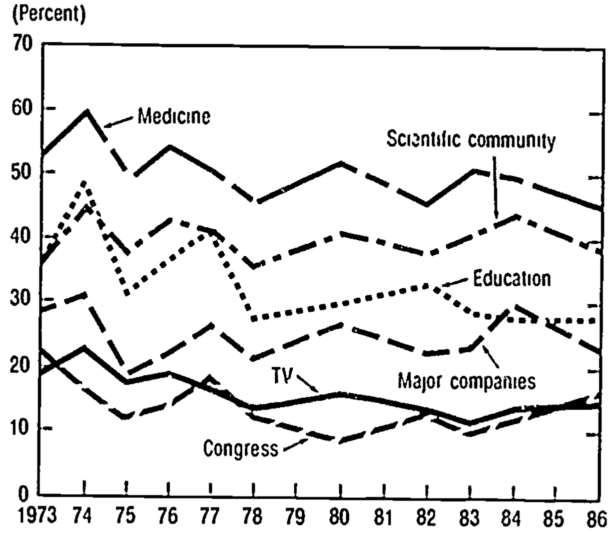
[30]Seven percent disagreed, 7 percent neither agreed nor disagreed, and 2 percent had no opinion.

[31]Thirty-two percent favor robots, 34 percent oppose, and 34 percent did not respond to this item on the list. The French seem to be slightly more negative In the 1982 French survey, only 13 percent were in favor of speeding up the development of robots capable of doing precise factory work rapidly; 46 percent wanted to restrain robot development, and 39 percent wanted to let these machines be put in place gradually. See Bon and Boy (1984b), p. 43.

[32]In the U S , 49 percent agree, 46 percent disagree, and 4 percent have no opinion. In Great Britain, 57 percent agree, only 16 percent disagree, and 28 percent have no opinion.

[33]In the U.S., 77 percent believe this, while 19 percent disagree, and 4 percent don't know. In Britain, only 34 percent agree, 30 percent disagree, and 36 percent don't know. An internationally coordinated public opinion survey on the impact of information technology on employment is Vine (1985). The survey was done in 1985 and covered the United States and Japan, in addition to six Western European countries.

Figure 8-2.
**Percent of public expressing a great deal of confidence in people running selected institutions**




See appendix table 8-12

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### Attitudes Toward Scientists

An important component of the public's view of science is its view of scientists themselves. Such attitudes are brought to bear when students decide whether to become scientists on the basis of their own and their parents' view of the kind of person a scientist is. Moreover, the public's acceptance of views expressed by scientists on science-related controversies is presumably influenced by their picture of the scientist as a person.

The data show that leaders of the scientific community continue to enjoy high confidence as compared with leaders of other institutions. (See figure 8-2. For the rest of the list, see appendix table 8-12.) This indicator is understood to represent the level of confidence in the institutions themselves.[34] While the data show fluctuations of public confidence in institutions in general—and long-term trends in the standing of certain institutions in particular—medicine has consistently led the list in terms of public confidence. The scientific community has almost as consistently been in second place. This is a very positive result from the point of view of the scientific community, especially since medicine is also a highly science- and technology-oriented profession. However, the scientific community also consistently receives the greatest number of "don't know" responses; this suggests uncertainty or a lack of familiarity with this community. Males and college graduates show relatively high levels of confidence in scientific leaders

The responses to two other questions provide further information on the public's perception of scientists. One

[34]Smith (1981)

**Table 8-12. Public's image of scientists, by attentiveness: 1985**

| Statement | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Scientific researchers are dedicated people who work for the good of humanity. | | | | |
| Agree | 80 | 79 | 78 | 81 |
| Disagree | 16 | 15 | 18 | 15 |
| Don't know | 4 | 6 | 5 | 4 |
| Because of their knowledge, scientific researchers have a power that makes them dangerous. | | | | |
| Agree | 55 | 48 | 54 | 57 |
| Disagree | 42 | 51 | 42 | 38 |
| Don't know | 4 | 2 | 3 | 5 |
| N = | 2,005 | 417 | 517 | 1,071 |

"For each statement, tell me if you generally agree or generally disagree."

See appendix table 3-13. Science & Engineering Indicators—1987

question was positively oriented and asked whether scientific researchers are dedicated people who work for the good of humanity. The other asked whether researchers have a power that makes them dangerous (See table 8-12.) There was strong agreement with the positive evaluation. Moreover, there was virtually no variation by gender, education, or age, although respondents with graduate degrees were slightly less likely to share this opinion. The negative question, measuring public apprehension about the power of scientific researchers, produced a small majority expressing this concern. Responses here varied by gender and education (See appendix table 8-13.) Since this is the one question that brought out a clearly negative reaction to scientists, further exploration would be useful to ascertain the "danger" respondents see. The negative outcomes suggested by tables 8-8 and 8-9 may provide part of the answer

The question about scientists being dedicated people who work for the good of humanity was also asked in France and Japan. In 1982, French respondents gave almost exactly the same response as the Americans (82 percent agreed, 14 percent disagreed, 4 percent didn't know).[6] In 1987, 73 percent of the Japanese agreed that scientists are striving for mankind, 16 percent disagreed, and 11 percent didn't know. The answers from all three countries to this question are broadly similar[7]

On the other (negative) question, 73 percent of the French in 1982 believed that scientific researchers, because of their knowledge, have a power that can make them dangerous. Among the Japanese, 27 percent agreed that scientists are dangerous because of their abundant knowledge, while 56 percent disagreed, and 17 percent didn't know. The Japanese response to the question is more favorable to scientists than the answers from the other two countries. (Compare table 8-12 )

## Acceptance of Scientific Thinking

In order to best communicate science- and technology-related information to the public, the scientific and technological community needs to know the degree to which the public accepts scientific thinking. Such communication may relate to health and nutrition, the safety of nuclear power plants or airline travel, or the accomplishments of the national space program. Regardless of the topic, if the public does not accept scientific thinking in general, the impact of these communications on specific issues may be lost.

No exact measures of "scientific" thinking have been agreed upon, nor is it suggested that there is an absolute standard of scientific thinking against which the respondents can be judged. What is possible, however, is to identify relatively familiar science- and technology-related topics with some popular appeal, and to compare public opinion on these topics with common scientific opinion. In this way, public acceptance of science and technology may be estimated. Six such topics have been studied. (See table 8-13.)

Broad public acceptance was found for both the concept of continental drift and the health hazards of smoking. (See table 8-13.) These results suggest that the extensive media discussion of plate movement and earthquakes has made some impression on public thinking. Similarly, the wide coverage of the smoking and health issue and the strong endorsement of the antismoking campaign by the medical community have significantly affected public attitudes. As might be expected, attentives show the most support for the scientific position, followed by the interested public and the remaining public.

On the other four items, from 43 to 47 percent of the public do not hold the usual scientific opinion.[8] On only one of them (lucky numbers) do those who accept the

[6] See Bon and Boy (1984b), p. 17.

[7] In the French study, 47 percent agreed that scientists work to satisfy their curiosity more than to help people In Japan, the acceptance of this idea was somewhat less (37 percent).

[8] This may be because of either unfamiliarity with the scientific opinion or rejection of it At present these two reasons cannot be separated



16

**Table 8-13. Public opinion on scientific questions: 1985**

| Questions and responses | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Smoking causes serious health problems. | | | | |
| Agree | 95 | 97 | 95 | 94 |
| Disagree | 4 | 3 | 4 | 4 |
| Don't know | 1 | 1 | 1 | 2 |
| The continents on which we live have been moving their location for millions of years and will continue to move in the future. | | | | |
| Agree | 79 | 89 | 82 | 74 |
| Disagree | 12 | 8 | 11 | 14 |
| Don't know | 9 | 3 | 7 | 12 |
| In the entire universe, it is likely that there are thousands of planets like our own on which life could have developed. | | | | |
| Agree | 65 | 72 | 70 | 60 |
| Disagree | 25 | 21 | 24 | 28 |
| Don't know | 10 | 7 | 6 | 12 |
| Human beings as we know them today developed from earlier species of animals. | | | | |
| Agree | 45 | 56 | 47 | 41 |
| Disagree | 47 | 40 | 46 | 51 |
| Don't know | 7 | 4 | 7 | 9 |
| It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations. | | | | |
| Agree | 43 | 46 | 42 | 42 |
| Disagree | 46 | 44 | 45 | 47 |
| Don't know | 11 | 10 | 12 | 11 |
| Some numbers are especially lucky for some people. | | | | |
| Agree | 43 | 36 | 48 | 44 |
| Disagree | 53 | 62 | 49 | 51 |
| Don't know | 4 | 2 | 4 | 5 |
| Rocket launchings and other space activities have caused changes in our weather. | | | | |
| Agree | 44 | 34 | 41 | 49 |
| Disagree | 44 | 58 | 47 | 37 |
| Don't know | 12 | 8 | 12 | 14 |
| N = | 2,005 | 417 | 517 | 1,071 |

"For each statement, please tell me if you generally agree or generally disagree."

See appendix table 8-14.

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scientific view significantly outnumber those who reject it. Attentives accept the scientific view more frequently than others in three of these four cases (effect of rocket launchings on the weather, lucky numbers, and human evolution). In the case of unidentified flying objects (UFO's), attentives show, if anything, a slightly greater tendency than others to believe in their existence. This is, of course, a subject which has received a great deal of fictional treatment and one which many do not consider to be settled. It also is noteworthy that fully 40 percent of the attentive public do not believe in human development from earlier animal species, and one-third believe in lucky numbers or in the effect of human space activities on the weather. On the basis of these findings, it is fair to say that large numbers of Americans do not accept scientific views on many everyday questions.

Certain characteristics of the public help to explain these responses. For example, men are much more likely than women to accept evolution and much less likely to believe that space activities affect the weather. Age also affects the responses to the individual questions—though in widely different ways. Younger people are more likely to believe in evolution, but they are also more likely to believe in UFO's. Belief that space activities have affected the weather tends to be found at the two extremes: among both the youngest and oldest respondents.[39] Educational level is, as always, strongly associated with acceptance of the usual scientific opinion The single exception is belief in UFO's, where there is only a slight variation of response with educational level, and the frequency of a "not sure" response is especially high at all educational levels. Even at the highest educational level, however, about one-fourth of Americans with graduate degrees believe space activities affect the weather, believe in lucky numbers, or do not believe in evolution.

The Japanese public has interesting similarities and dissimilarities in its opinions on these questions. (See table 8-14.) Both publics are strongly in agreement about the dangers of tobacco and about the reality of continental drift. Regarding life on other planets and UFO's, the Japanese show lower levels of acceptance and higher levels of "don't know" responses than the Americans surveyed.[40] The greatest disagreement concerns the questions regarding evolution, where the Japanese showed much higher levels of acceptance and lower levels of rejection than did the Americans. Differences of question wording in the two surveys may be significant. Even so, among the five questions common to the two surveys (compare table 8-13 with table 8-14), the evolution question ranks third on the Japanese list in terms of acceptance but only fourth or fifth on the American list. This is the only item of the five in which the Japanese and American ordering of the items is different, so that there is a genuine difference between the two publics in terms of accepting evolution.

### Limits and Alternatives to Scientific Thinking

The public's acceptance of scientific thinking can also be seen in its view of the scope and limits of science. (See table 8-15.) For example, public reaction on two issues has been studied. scientific understanding of the human mind and alternative medicines not recognized by science. Both of these should probably be thought of as areas in which science has much to learn and on which it may develop clearer positions in the future. A majority of respondents agreed that the human mind is not as accessible to science as is the physical world. Even alternatives support this position. A similar view was expressed in 1979, when only 23 percent agreed that we can, by scientific study, find out "just about everything" about human behavior. (Another 68 percent said "some things but not others."[41]) A large majority agrees that there are good ways of treating sickness that medical science does not recognize.[42] These two questions suggest that there is an area of personal life and values in which the public feels that science does not have the last word.

Astrology is a method of analyzing human characters and of predicting the future that scientists generally consider to have been refuted by the development of science. Adherence to astrology thus is another indicator of acceptance (or nonacceptance) of scientific thinking. About 15 percent of the public reads astrology reports "every day" or "quite often." In 1979, 21 percent reported doing this.[43] Only 8 percent said they decide to do or not do something because of their astrological forecast for that day. (See table 8-15.[44] The figure in 1979 was 5 percent; the rise from 1979 to 1985 is statistically significant at the 95-percent level.) Belief in astrology therefore is not nearly as widespread as the belief that science has limitations with regard to the human mind and the belief in alternative medicine. There is some confusion about astrology's status as a science: 8 percent of the public regard astrology as "very scientific" and 31 percent regard it as "sort of scientific."[45] If the public is not clear about what is and is not a science, then it also may not be clear on what views are regarded as scientific. This may help to explain the lack of acceptance of scientific thinking illustrated on table 8-13.

Belief in the limits of science is broadly distributed in the population. In terms of age, for example, it is the youngest group (age 18-24) and the oldest group (65+) that believe most in astrology and in the limits of science in understanding the human mind. Thus, belief in the limits of science is not simply associated with an older generation possibly clinging to outdated, nonscientific values. There is also a youthful component that shares

[39]For a study of the acceptance of pseudosciences by various elements of the French public, see Boy and Michelat (1984), pp. 1560-1567. On the acceptance of parapsychology and similar phenomena in the United States, see Greeley (1987), pp. 47-49.

[40]The 1982 French survey found 33 percent believing in UFO's, 57 percent not believing, and 11 percent "don't know's." See Bon and Boy (1984b), p. 9. This is slightly more skeptical than the American and Japanese responses.

[41]See National Opinion Research Center (1980), p. 254. The 1982 study of the French population found 36 percent who disagreed with the statement that science will make it possible to understand the functioning of the human mind completely, 56 percent accepted some degree of possibility that this may happen, and 9 percent had no opinion. See Bon and Boy (1984b), p. 13. In the 1987 Japanese study, 85 percent agreed that even if science and technology develop, they cannot explain man's mind. Eight percent disagreed and 6 percent had no opinion. There are differences of questions wording—especially regarding the French question—but the Japanese response seems more skeptical about the capabilities of science than does the American response.

[42]In the French study, 54 percent said that there certainly or possibly are illnesses that it is better to treat by means other than medicine Thirty-seven percent disagreed and 10 percent had no opinion. See Bon and Boy (1984a), p. 13. In the Japanese study, 73 percent agreed that for some illnesses, it is better to be treated by methods other than modern medicine, 18 percent disagreed and 9 percent had no opinion The Japanese response seems quite similar to the American, while the French response seems more supportive of the exclusive claims of medical science.

[43]See National Opinion Research Center (1980), p. 276 Some difference between the questions used in the two years should be noted

[44]Similarly, 8 percent of the French population reported in 1982 that they take account of horoscopes in their lives "always" or "often." See Bon and Boy (1984b), p. 10, and Bon and Michelat (1984) Thirteen percent of Japanese respondents stated that they change their actions according to their horoscope for a given day In France and Japan, interest in astrology increases the younger the respondent is, in the United States, interest increases among both the youngest and the oldest respondents.

[45]Fifty-seven percent regard it as not at all scientific In France, astrology seems to be even more widely respected with 53 percent stating that it is a science and only 30 percent that it is not The rest say it depends on the case (8 percent) or don't know (8 percent) See Bon and Boy (1984b), p. 11.

### Table 8-14. Japanese public's opinion on scientific questions: 1987

| Questions | Agree | Disagree | Don't know |
|---|---|---|---|
| | Percent | | |
| Tobacco has a very bad effect on human health ..... | 90 | 8 | 2 |
| The continents are moving slowly over the course of many millions of years ........................... | 78 | 5 | 17 |
| Humans have evolved from animals ................ | 75 | 12 | 13 |
| Just as on earth, there are a great many planets in the universe on which life forms exist .................. | 49 | 22 | 29 |
| UFO's are real .............................. .... | 34 | 35 | 31 |
| N = 2,334 | | | |

"What do you think of the following matters?"

SOURCE: Office of the Prime Minister of Japan (1988)

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### Table 8-15. Public views of the limits of science: 1985

| | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Scientists will never be able to understand the working of the human mind as well as they understand the physical world. | | | | |
| Agree .............................. | 59 | 52 | 60 | 62 |
| Disagree ........................... | 35 | 43 | 36 | 31 |
| Don't know ......................... | 6 | 5 | 5 | 7 |
| There are some good ways of treating sickness that medical science does not recognize. | | | | |
| Agree .............................. | 75 | 72 | 76 | 76 |
| Disagree ........................... | 17 | 21 | 16 | 17 |
| Don't know ......................... | 7 | 6 | 7 | 7 |
| Would you say that astrology is . . . | | | | |
| Very scientific ....................... | 8 | 6 | 9 | 9 |
| Sort of scientific ..................... | 31 | 30 | 30 | 31 |
| Not at all scientific .................. | 57 | 60 | 59 | 55 |
| Don't know ......................... | 4 | 4 | 2 | 5 |
| Do you sometimes decide to do or not do something because your astrological signs for the day are favorable or unfavorable? | | | | |
| Yes ................................ | 8 | 8 | 8 | 8 |
| No ................................. | 88 | 90 | 88 | 86 |
| Don't know ......................... | 4 | 2 | 4 | 6 |
| N = | 2,005 | 417 | 517 | 1,071 |

See appendix table 8-15.

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some of these doubts.[16] No gender differences are significant, except for the larger number of women who act on astrological forecasts. Education is strongly related to belief in astrology; 17 percent of those without a high school education sometimes act on astrological forecasts. This includes 13 percent of the men without a high school education and 22 percent of the women.[17] Similarly, those with lower levels of education are more often convinced that the human mind is inaccessible to science. The question about treatments that medical science does not recognize has virtually no dependence on demographics: about three-quarters of every group surveyed (as shown on appendix table 8-15) believe that there are good methods of treating illness outside medical science.

[16]For a discussion of this phenomenon in the French context, see Boy and Michelat (1984).

[17]Miller (1988).

**Table 8-16. Public perception of U.S. standing in science and technology in comparison with other countries: 1985**

| Area and country | Percent considering the U.S. Ahead | Same | Behind | Don't know |
|---|---|---|---|---|
| | Percent | | | |
| Basic scientific achievements: | | | | |
| Japan | 36 | 30 | 29 | 6 |
| Soviet Union | 43 | 33 | 15 | 8 |
| West Germany | 58 | 27 | 7 | 7 |
| Great Britain | 70 | 18 | 3 | 8 |
| France | 75 | 14 | 3 | 8 |
| Military technology: | | | | |
| Soviet Union | 33 | 40 | 20 | 6 |
| West Germany | 70 | 21 | 3 | 5 |
| Japan | 73 | 16 | 5 | 5 |
| Great Britain | 76 | 16 | 1 | 6 |
| France | 80 | 12 | 2 | 6 |
| Civilian or industrial technology: | | | | |
| Japan | 11 | 18 | 66 | 4 |
| West Germany | 49 | 35 | 10 | 6 |
| Great Britain | 69 | 21 | 3 | 7 |
| France | 73 | 18 | 3 | 6 |
| Soviet Union | 75 | 15 | 4 | 6 |
| N = 2,005 | | | | |

"In terms of basic scientific achievements, would you say that the United States is ahead of West Germany, behind West Germany or at about the same level?"

See appendix table 8-16. Science & Engineering Indicators—1987

## U.S. Versus Foreign Science and Technology

Besides considering public acceptance of scientific thinking in general, the survey measured the public's views of American science and technology in comparison with the efforts of other countries. The resulting information reflects the influence on public opinion of news items about unfavorable changes in the balance of trade, weaknesses in the U.S. educational system, Nobel prizes received by Americans, and foreign efforts to acquire U.S. military technology. The question was asked separately about basic science, military technology, and industrial or civilian technology, rather different responses were received in each case. (See table 8-16.)

With regard to basic science, the majority agrees that the U.S. is ahead of Germany, France, and Britain. The most common opinion is that the U.S. is also ahead of the Soviet Union and Japan. Many think, however, that the U.S. is at about the same level as or even behind these two countries.[18] For this question, the attentives have the greatest confidence in U.S. achievements, the interested public the next highest level of confidence, and the remaining public the least. (See appendix table 8-15.)

With respect to military technology, high percentages believe that the U.S. is leading the other noncommunist countries, including Japan. On the other hand, the most common opinion about the Soviet Union is that it is on the same level as the United States. Fewer Americans think the U.S. is leading the Soviet Union in military technology than in basic science. Except in the case of the U.S.S.R., there is little difference between the responses of the attentive and the interested public on this question. Both groups, however, are more optimistic about U.S. accomplishments than is the remaining public

In the case of industrial or civilian technology the responses are quite different. A large majority thinks the U.S. is behind Japan, this response does not occur with any other field or any other country. Majorities put the U.S. ahead of Britain and France; there is weaker agreement that the U.S. is ahead of West Germany. There is a clear belief that the U.S. is leading the U.S.S.R., which is not the case when speaking of basic science or military technology On this question, there was much less difference of opinion among the attentives, the interested public, and others. Only with regard to France and Britain is there a significant gap among the groups: it occurs between the interested public and the remaining public.

These results show that there is a general feeling that the U.S. leads France, Britain, and—to a lesser extent—West Germany in science and technology.[19] U.S. superi-

[18] A CBS News *New York Times* poll from September 15-19, 1985 found 14 percent saying that the Soviet Union is better than the United States in scientific research, while 67 percent think the U.S. is better.

[19] The 1982 French study found that the French consider themselves behind the Americans, Japanese, Soviets, and West Germans in scientific and technical accomplishments, but at the same level as or ahead of the British. See Boy and Boy (1983), p. 52

ority to West Germany is considered greatest in military technology. This may be because that country is not a nuclear power, yet West Germany is considered stronger than France and Britain, which are nuclear powers.

With respect to Japan and the Soviet Union, it makes a great difference whether one is talking about basic science, military technology, or civilian technology.[50] Japan is given high marks in basic scientific research, but as a non-nuclear power with minimal armed forces, it is seen to be well behind the U.S. in military technology. The public has reacted very strongly to the Japanese achievement in technology and trade by placing Japan far ahead of the United States in industrial technology. The high rating given to Japan in basic science may partly reflect the American public's perception of this success in technology and trade. The Soviets are also given relatively good marks in basic scientific research. But, unlike the Japanese, their military technology is rated higher than their ranking in basic research would suggest, while their civilian technology is rated lower.

The Japanese public, in the 1987 survey, were also asked to compare various countries with respect to various aspects of science and technology. The same six countries discussed above were ranked from 1 to 6 according to their degree of progress in basic science and technology, industrial technology, and technology related to everyday living.[51] (See table 8-17. For the average rankings, see appendix table 8-17.)

The Japanese consider the United States to be clearly ahead of them in basic science and technology. They consider themselves ahead of all the other countries, however, with the Soviet Union the closest competitor. This is very similar to the ranking that Americans give to these countries with respect to basic scientific achievements (see table 8-16), except that Americans are not as convinced that their country is ahead of Japan. Although the Japanese consider the United States to be leading in all three aspects of science and technology (see appendix table 8-17), it is with respect to basic science and technology that the United States is given the greatest advantage relative to the other countries.

With respect to industrial technology, the Japanese again consider the United States to be leading Japan, but only by a very small margin.[52] Other countries are far behind. This is the area in which the Japanese rank themselves closest to the United States. (See appendix table 8-17.) This ranking, however, is nothing like the American view that Japan is clearly leading in civilian or industrial technology. (See table 8-16.)

The Japanese study also asked for a ranking of countries regarding technology related to everyday living. The United States was clearly placed ahead of Japan in this area, in spite of Japanese accomplishments in consumer electronics and other household products. In this case, the Soviet Union was rated the lowest of the six countries. This is similar to the U.S. survey, which ranked the Soviet Union lowest in civilian or industrial technology. (See table 8-16.)[53]

## SCIENCE AND TECHNOLOGY POLICY AREAS

### Funding for Basic Research

A number of specific policy areas were selected for special study. These supplement the rather broad questions discussed above by moving away from science and technology in general and into matters of practical concern. For example, 79 percent of the public believe that the Federal Government should support research that advances the frontiers of knowledge, even if this research brings no immediate benefits. (See table 8-18.) The public therefore does not expect all Federal research funding to be devoted to specific applications. Stronger support for basic research funding is found among more educated people, as in other cases, and also among those aged 25-34. (See appendix table 8-18.)

### Restriction of Research

Another policy issue involves the public's wish that scientists not be allowed to conduct research on certain topics. The freedom to select their own research questions is considered a precious right by most scientists; it is recognized, however, that the public has a growing interest in what research is conducted and to what ends. Given a list of research areas, the public would not like to see research prohibited in most of them, attentives are against the restraint even more than are others. (See table 8-19.[54]) One exception to this, however, is research designed to create new biological or chemical weapons, which about two-thirds of each group is willing to restrain. Also, in 1983, about as many were opposed to research that would enable parents to select the sex of their child. (See appendix table 8-19.) Another area provoking strong resistance is the kind of study that might lead to the creation of new life forms. The response to this question seems to depend strongly on question wording. Opposition is considerably greater when there is no specific mention of plant and animal life. (See appendix table 8-19.) In this case, respondents seem to be reacting to a vague notion of some nondescript life form.

It is notable that there is no widespread opposition to the controversial practice of medical experimentation on animals. This is true even for such domestic animals and primates as dogs and chimpanzees. (See appendix table 8-19.) An Associated Press poll in 1985 found strong

[50]The responses on table 8-16 suggest that the public is sometimes able to make the distinction between science and technology.

[51]Because of the way the question was asked, one country could not be on the same level as another, so that there is no column labeled "same" on the table.

[52]More detailed data show that 43 percent of respondents ranked the United States first, and the same percent ranked Japan first. However, 38 percent ranked the United States second, while only 28 percent ranked Japan second. Consequently, the United States has a small lead in the average rankings. (See appendix table 8-17.)

[53]Thus, the Japanese survey seems to have split the U.S. survey item on civilian or industrial technology into two items: industrial technology and technology related to daily living.

[54]In many of these cases, respondents may be evaluating the stated outcomes of the research, rather than the desirability of curbing the research itself. On the response of attentives, see Miller (1988).

**Table 8-17. Japanese public's perception of Japan's standing in science and technology in comparison with other countries: 1987**

| Area and country | Percent considering Japan | | |
|---|---|---|---|
| | Ahead | Behind | Don't know |
| Basic science and technology: | | | |
| United States | 20 | 73 | 7 |
| Soviet Union | 53 | 37 | 9 |
| West Germany | 60 | 28 | 12 |
| Great Britain | 76 | 11 | 13 |
| France | 78 | 8 | 14 |
| Industrial technology: | | | |
| United States | 46 | 48 | 7 |
| West Germany | 72 | 15 | 14 |
| Soviet Union | 74 | 15 | 11 |
| Great Britain | 78 | 7 | 16 |
| France | 79 | 4 | 16 |
| Technology related to everyday living: | | | |
| United States | 37 | 55 | 8 |
| West Germany | 66 | 20 | 15 |
| Great Britain | 71 | 14 | 15 |
| France | 72 | 12 | 16 |
| Soviet Union | 77 | 10 | 13 |
| N = 2,334 | | | |

"For each of the areas listed below please rank the following countries according to their degree of progress."

See appendix table 8-17. Science & Engineering Indicators—1987

**Table 8-18. Public support for basic scientific research, by attentiveness: 1985**

| | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Federal Government. | | | | |
| Agree | 79 | 88 | 83 | 73 |
| Disagree | 16 | 10 | 15 | 19 |
| Don't know | 5 | 3 | 3 | 7 |
| N = | 2,005 | 417 | 517 | 1,071 |

See appendix table 8-18. Science & Engineering Indicators—1987

support for experimentation on animals for the purposes of research on specific diseases (81 percent), basic research (72 percent), and allergy testing (61 percent).[55] While 76 percent of respondents thought that animals have rights, 38 percent of those with that opinion believed that the use of animals in medical research does not violate those rights. On the other hand, 46 percent of those believing animals have rights—or 35 percent of the entire sample—believed that experimentation does violate animal rights. This is similar to the 30 percent on table 8-20 who do not believe that scientists should be allowed to conduct such studies. The AP study found that approval for animal experimentation varies with the type of animal, ranging from rats (88 percent) and rabbits (77 percent), to monkeys (69 percent), cows (58 percent), and dogs (55 percent).[56]

[55]Associated Press/Media General (1985).

[56]The British public seems more opposed to experimentation on animals. When asked about medical research using animals to test drugs, 26 percent in 1985 mentioned this as something they favored developing further, 46 percent mentioned it as something they did not favor, and 27 percent did not respond. See MORI (1985), p. 9. By comparison, 63 percent of the American respondents in 1985 said that scientists should be allowed to conduct studies on animals under stated conditions. (Cf. table 8-19.)

Table 8-19. Percent of U.S. and Japanese publics willing to allow research to be conducted in certain areas

| Subject and country | Should be allowed | Should not be allowed | Don't care,[1] don't know |
|---|---|---|---|
| | ——— | Percent | ——— |
| Studies that might enable most people in society to live to be 100 or more: | | | |
| United States | 68 | 26 | 6 |
| Japan | 20 | 51 | 29 |
| Studies that cause pain or injury to animals like dogs and chimpanzees, but which produce new information about human disease or health problems: | | | |
| United States | 63 | 30 | 7 |
| Japan | NA | NA | NA |
| Studies that might discover intelligent beings in outer space: | | | |
| United States | 64 | 29 | 6 |
| Japan | 21 | 49 | 30 |
| Studies that might lead to precise weather control and modification: | | | |
| United States | 60 | 36 | 4 |
| Japan | 36 | 44 | 20 |
| Studies that might allow scientists to create new forms of plant and animal life: | | | |
| United States | 52 | 42 | 6 |
| Japan | 10 | 67 | 22 |
| Studies that are designed to create new biological or chemical weapons: | | | |
| United States | 29 | 66 | 6 |
| Japan | NA | NA | NA |

N (United States, 1985) = 2,005
N (Japan, 1987) = 2,334

[1] This response was explicitly offered to the respondents in the U.S. survey. In the Japanese survey it was not, but was recorded if the respondent offered it. This difference would tend to increase the relative numbers of Americans giving this answer.

SOURCES: Japan: Office of the Prime Minister of Japan (1987); United States: Miller (1988)

See appendix table 8-19. Science & Engineering Indicators—1987

The Japanese public is more willing than the American public to stop research in certain areas. (See table 8-19.) Four questions were asked paralleling those in the American survey.[57] In each case, more respondents wished to stop the research than wished to pursue it.[58] The Japanese response thus was more negative than the American in every case. The Japanese were most negative about research to create new life forms, which was also an area of concern to Americans.[59] On the other hand, the Japanese gave their highest support to research designed to lead to weather control.

## Government Regulation of Science and Technology

A similar question has to do with the proper level of regulation of scientific and technological activities by government. The reply can serve as an indicator of the level of public comfort or discomfort regarding those

[57] The American question was "For each study, please tell me whether you think scientists should or should not be allowed to conduct this kind of research. If you don't care one way or the other, just give that answer." In Japan, the question was "Do you think the following types of research should be pursued? Or should they be stopped?"

[58] There was also quite a high level of "don't know" responses, so that altogether the responses supporting the several areas of research were distinctly lower than in the American survey.

[59] The British also have strong feelings about such research. When asked whether they favored further developments in cross-breeding of different species of animals, only 7 percent responded affirmatively. Sixty-eight percent mentioned this as a development they would oppose being further developed, and 27 percent did not mention this subject. See MORI (1985), p. 9. This was the least favored of the 26 possible developments offered.

Table 8-20. U.S. and Japanese opinions concerning present levels of government regulation of various areas of science and technology

| Area | Too low | About right[1] | Too high | Don't know |
|---|---|---|---|---|
| | Percent | | | |
| Use of food additives: | | | | |
| United States .................... | 38 | 25 | 30 | 7 |
| Japan .......................... | 79 | 12 | 3 | 6 |
| Construction of atomic power plants: | | | | |
| United States .................... | 29 | 34 | 30 | 7 |
| Japan .......................... | 54 | 29 | 6 | 11 |
| Manufacture of new pharmaceuticals: | | | | |
| United States .................... | 21 | 55 | 16 | 8 |
| Japan .......................... | 54 | 23 | 13 | 10 |
| Genetic engineering research: | | | | |
| United States .................... | 20 | 42 | 16 | 22 |
| Japan .......................... | 42 | 26 | 10 | 21 |
| Basic research: | | | | |
| United States .................... | 17 | 56 | 12 | 15 |
| Japan .......................... | 18 | 46 | 16 | 19 |

N (United States, 1985) = 2,005
N (Japan, 1987) = 2,334

United States: "I'm going to read you a short list of activities, and for each one I'd like for you to tell me whether you think that the present level of governmental regulation is too high, too low, or about right."

Japan: "For the following issues, do you think that government regulations should be tightened or loosened?"

[1] This response was offered explicitly to the respondents in the U.S. survey. In the Japanese survey it was not, but was recorded if the respondent offered it. This difference would tend to increase the relative numbers of Americans giving this answer.

SOURCES: United States: Jon D. Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

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activities. Both the Japanese and American publics were asked whether the present level of regulation in their countries is too low or too high in certain areas. (See table 8-20.) Both groups agreed that the level of regulation in the area of basic research is about right, making this the least feared area of activity.[60]

In the other cases, the Japanese showed notably more desire for increased regulation than did the Americans. Japanese are especially concerned about chemical food additives; they also show a strong desire for more regulation of nuclear power plants. In both of these cases, Americans are about equally split regarding more or less regulation.[61] With regard to pharmaceutical manufacture and genetic engineering research, Americans still more strongly tend to accept the status quo, with large numbers not wishing to see any change and the remainder about equally divided for more and for less regulation. For these two technologies also, there seems to be a much greater concern among the Japanese, and more desire to see increased regulation.[62]

## Advantages versus Disadvantages of Various Technologies

The American respondents were asked to assess three policy areas in terms of the balance between the benefits and harms they have brought. In all three cases, there is more public support than resistance although nuclear power shows an amount of resistance nearly equal to the amount of support. (See table 8-21.) Nuclear power is also the only area where attentives have a high level of resistance and where there is not a greater level of support among attentives than among others. However, large minorities also express negative assessments of space exploration and genetic engineering.

These reactions also can be studied in terms of respondents' demographic characteristics. (See appendix table 8-20.) Women are more critical of all three technologies than are men, especially in the case of nuclear power. Education is strongly correlated with support of

[60] Since basic research and genetic engineering research received large numbers of "don't know" responses from both the Japanese and Americans, it is fair to surmise that these are relatively unfamiliar areas for many people.

[61] The 1982 French survey found only 21 percent in favor of adding preservatives to foods, while 75 percent were opposed and 4 percent had no reply. See Bon and Boy (1984a), p. 33. Thus the French seem to share the Japanese concern on this subject.

[62] It should be noted that the American survey was performed before the accident at the Soviet nuclear plant at Chernobyl, while the Japanese survey was performed after it. Possibly this fact helps to explain the more negative Japanese responses.

**Table 8-21. Public assessment of three policy areas, by attentiveness: 1985**

| Area and assessment | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent agreeing | | | |
| Space exploration: | | | | |
| Benefits greater than costs | 53 | 64 | 57 | 47 |
| Benefits equal costs[1] | 2 | 2 | 4 | 2 |
| Costs greater than benefits | 40 | 29 | 35 | 46 |
| Don't know | 5 | 5 | 4 | 5 |
| Genetic engineering research: | | | | |
| Benefits greater than risks | 49 | 56 | 52 | 45 |
| Benefits equal risks[1] | 2 | 2 | 1 | 2 |
| Risks greater than benefits | 39 | 35 | 35 | 41 |
| Don't know | 10 | 6 | 11 | 12 |
| Nuclear power: | | | | |
| Benefits exceed risks | 49 | 49 | 52 | 48 |
| Benefits equal risks[1] | 1 | 1 | 1 | 2 |
| Risks exceed benefits | 45 | 48 | 42 | 44 |
| Don't know | 4 | 2 | 5 | 5 |
| N = | 2,005 | 417 | 517 | 1,071 |

"In your opinion, have the costs of space exploration exceeded its benefits, or have the benefits of space exploration exceeded its costs?"

[1] Volunteered by respondents.

See appendix table 8-20.

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space exploration and genetic engineering research."[6] In the case of nuclear power, there is no strong relationship between education and one's benefit/risk assessment; there is, however, a strong trend with age, with younger respondents being more critical.

## REACTIONS TO CHALLENGER AND CHERNOBYL ACCIDENTS

Technological disasters like the Challenger and Chernobyl accidents may influence general public perceptions regarding science and technology. The main survey reported in this chapter was performed in November-December of 1985. To capture information related to these major events, two supplementary surveys were conducted. The first supplementary survey was scheduled in response to the January 28, 1986, explosion of the Space Shuttle Challenger. To investigate the effects of this accident on public opinion, the respondents interviewed in late 1985 were reinterviewed immediately after the accident, in January-February of 1986. At the time of this supplementary survey, the accident was fresh in people's minds and the President had just addressed the Nation on television, strongly supporting the continuation of the space program.

Several months later, the Rogers Commission report was published, reinforcing news reports about defective O-rings in the rocket boosters and management failings as having contributed to the accident. To measure the effect on public opinion of this information, and to determine whether the first reactions to the accident had persisted, a second supplementary survey was done in June-July of 1986.

Between these two supplementary surveys, another technological disaster came to public attention. In April 1986, the Soviet nuclear power plant at Chernobyl experienced a major accident, and released radioactive materials into the environment. The June supplementary survey thus provided an opportunity to measure changes in attitudes toward nuclear power also. Both supplementary surveys were able to take advantage of the baseline survey that had been done in late 1985, before either accident had occurred.

### Reactions to Space Shuttle Accident

In February 1986, right after the Challenger accident, only a minority considered it a major setback for the space program, and nearly everyone thought the manned shuttle flights would be resumed. (See table 8-22.) With regard to the accident's causes, people were about evenly divided as to whether there was a basic design error or a flaw that might have led to the explosion. A majority believed that accidents could be expected from time to time in such complex machines as the shuttle and that the problems that had caused the accident would be found and corrected so that the shuttle program would continue. Soon after the explosion, the suggestion was made that manned flights be de-emphasized in favor of unmanned vehicles. Even the explosion did not lead to a majority favoring this alternative. About one-half were willing to see Federal funds for the program increased if they are needed to modify the shuttle program or get it back on schedule. A large majority said

[6] "Genetic engineering research also gets the highest number of "don't know" responses these are concentrated among older respondents and those with the lowest levels of education.

Table 8-22. Public reactions to the Shuttle Challenger accident

| | February 1986 | June 1986 |
|---|---|---|
| | Percent agreeing | |
| Accident was a major setback | 37 | 66 |
| Increase Federal funds for shuttle if needed | 50 | 49 |
| Accident reflects basic design flaw | 50 | 78 |
| Accidents will occur from time to time | 83 | 82 |
| Manned flights should be reduced | 31 | 43 |
| Shuttle is outstanding example of U.S. technology | 97 | 97 |
| Manned flights will be resumed | 98 | 98 |
| N = | 1,111[1] | 1,111 |

[1] Although the February 1986 samp.. was greater than 1,111, the results shown here apply to the same 1,111 people who responded in June 1986.

Note: For question wording see appendix table 8-21.

See appendix table 8-21. Science & Engineering Indicators—1987

the shuttle is still an outstanding example of American technology. In all, the first effect of the Challenger accident was a significant show of support for the space program.

In June 1986, after the Rogers Commission had reported, another survey was done, again interviewing the same respondents as far as possible. By this time, there had been a thorough discussion of the shuttle's technical and administrative problems. More respondents now believed that there was a basic design flaw and a majority was willing to characterize the accident as a major setback for the shuttle program. (See table 8-22.) More respondents also opted for reducing the number of manned flights. On other questions, there was very little change in opinion from February to June. The accident was attributed to the National Aeronautics and Space Administration (NASA) more often than to anyone else, and was blamed on the booster and the O-rings more than on any other cause. About 75 percent agreed that the shuttle would be safe to fly again once the rocket boosters were redesigned.[64] While a very large majority continued to believe that the shuttle is an outstanding example of American technology, the numb r who strongly agreed with this had dropped significant.y. (See appendix table 8-21.) Overall, while the respondents had formed some more negative judgments about the causes of the accident and its severity, they continued to be strong supporters of the program.[65]

## Attitudes Toward Space Program and Science and Technology Generally

The February 1986 supplementary survey, conducted immediately after the shuttle accident, provided an opportunity to ask some of the same questions about general attitudes toward science and technology that had been asked in November 1985. During this time, the respondents had changed somewhat their evaluations of the space program in general. (See table ᶜ .3.) The number considering the program's benefits to exceed its costs actually went up, particularly the number considering the benefits to greatly exceed the costs. The number[66] who considered the risks of nuclear energy and genetic engineering to strongly exceed their benefits went down from November to February. There was an increase in those strongly agreeing that science makes life healthier, easier, and more comfortable; that the Federal Government should support even research that brings no immediate benefits, and that new inventions will always be found to counteract the harmful consequences of technological development. The number agreeing that the benef..s of scientific research exceed the risks had increased after the accident. (See table 8-23.) However, the main change here was an increase in those who said the benefits are slightly greater; the number saying they are strongly greater decreased substantially. Except for this last result, the general effect immediately after the shuttle disaster was to rally support for the space program and other aspects of science and technology.

In June 1986, the question about the benefits and risks from science was asked aga. . At m( .t, from February to June a slight shift was found back to the opinion that the benefits of science are strongly greater than the risks, rather than slightly greater. (See table 8-23.) This change, however, was much smaller than that from November to February. With regard to space program costs and benefits, there was a decrease in those saying the benefits are greater than the costs and an i. crease in those saying the

[64] However, 30 percent thought it very likely—and 55 percent thought it possible but not likely—that there will be another shuttle accident within the next 25 years.

[65] In the June survey, 71 percent also agreed that the U.S. space program should build a space station, 53 percent said it should try to land astronauts on Mars in the next 25 years, and 50 percent said the U.S. should develop a scientific and mining colony on the moon in that time. See Miller (1987).

[66] Data discussed in the remainder of this paragraph are from Miller (1988).

**Table 8-23. Effect of the Challenger and Chernobyl accidents on general public attitudes toward science and technology**

| | November 1985 | February 1986 | June 1986 |
|---|---|---|---|
| | Percent | | |
| **Beneficial vs. harmful results of scientific research:** | | | |
| Balance strongly favors beneficial results | 47 | 20 | 22 |
| Balance only slightly favors beneficial results | 24 | 59 | 55 |
| About equal[1] | 5 | 4 | 3 |
| Balance only slightly favors harmful results | 12 | 7 | 5 |
| Balance strongly favors harmful results | 5 | 3 | 8 |
| Don't know | 7 | 6 | 5 |
| **Benefits of space program vs. costs:** | | | |
| Benefits substantially greater than costs | 30 | 37 | 33 |
| Benefits only slightly greater than costs | 25 | 28 | 27 |
| About equal[1] | 3 | 3 | 2 |
| Costs only slightly greater than benefits | 13 | 9 | 14 |
| Costs substantially greater than benefits | 26 | 16 | 18 |
| Don't know | 5 | 5 | 5 |
| **Benefits of nuclear power vs. risks:** | | | |
| Benefits substantially exceed risks | 30 | 23 | 26 |
| Benefits only slightly exceed risks | 20 | 30 | 26 |
| About equal[1] | 1 | 3 | 2 |
| Risks only slightly exceed benefits | 13 | 12 | 10 |
| Risks substantially exceed benefits | 31 | 26 | 28 |
| Don't know | 4 | 5 | 7 |
| N = | 1,111 | 1,111 | 1,111 |

[1] Volunteered by respondents.

Note: The same individuals were interviewed in all three surveys.

SOURCE: Jon D. Miller (1988)

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costs are greater. This change—while not enough to eradicate the increased support previously seen from November to February—suggests that news events after the explosion, including the publication of the Rogers Commission report, may have weakened the initial surge of support for the space program following the disaster.

### Attitudes Toward Nuclear Power

Some of the results discussed above also may have been affected by the accident at the Soviet nuclear plant at Chernobyl, which occurred in April 1986, between the February and June surveys. Most respondents thought that the Chernobyl accident was due to basic design flaws in the reactor although, perhaps paradoxically, a majority also thought the operators and managers at Chernobyl were at fault. (See table 8-24.) Other paradoxes also emerge: the respondents agreed by a small majority that the U.S. and other countries will primarily depend on nuclear sources of energy 50 years from now. At the same time, most agreed that solar energy is the best long-term solution to the energy problem. In any case, a very large majority agreed that science and technology will provide a long-term solution to the problem.

A very large majority also agreed that there are still major unanswered questions about the safety of nuclear power plants in all countries. Further, 49 percent of the public believed that another nuclear accident such as the one at Three Mile Island is "very likely" within the next 25 years. another 37 percent considered it at least possible.[illegible] This is highly similar to the opinion expressed in late 1985—before the Chernobyl accident (See table 8-9.) A small majority felt that the risk involved in generating nuclear power should block the construction of new nuclear power plants. There was no large shift in the public's

[illegible] See Miller (1988).

perception of the risk-benefit balance of nuclear power from the survey before the Chernobyl accident to the survey after. (See table 8-24.) In fact, larger shifts occurred between November 1985 and February 1986.

In summary, the Chernobyl accident elicited some expressions of uneasiness and uncertainty about nuclear power, but does not seem to have harmed the generally high level of public support for science and technology.

**Table 8-24. Public reactions to the Chernobyl nuclear plant accident: June 1986**

| | Agree | Disagree | Don't know |
|---|---|---|---|
| | Percent | | |
| The accident in the Soviet Union was the result of basic flaws in the design of the Chernobyl nuclear power plant | 72 | 15 | 13 |
| The operators and managers of the Soviet nuclear power plant at Chernobyl appeared to be at fault in the accident | 64 | 19 | 17 |
| Fifty years from now, all countries, including the United States, will depend primarily on nuclear power for the generation of electricity | 56 | 38 | 6 |
| Solar energy is the best long-term solution to our energy problem | 63 | 30 | 7 |
| We can depend on science and technology for a long-term solution to the energy problem | 89 | 8 | 3 |
| There are still major unanswered questions about the safety of nuclear power plants in all countries | 92 | 6 | 2 |
| The risk involved in generating nuclear power is relatively minor and should not block the construction of new nuclear power plants | 41 | 52 | 7 |
| N = 1,111 | | | |

SOURCE: Jon D. Miller (1988)

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## REFERENCES


Ancarrow, J.S., "Use of Computers in Home Study," (Washington, DC. U.S. Department of Education, Center for Education Statistics, 1987).

Associated Press/Media General poll, Sept 1-7 1985

Bon F. and D. Boy, "Évolution de l'Opinion Publique à l'Égard de la Recherche Scientifique entre 1972 et 1982," Centre de Prospective et d'Évaluation, Ministère de l'Industrie et de la Recherche (Paris: November 1983).

Bon F. and D. Boy, *La Science, la Technique et l'Opinion Publique en 1982*, Ministère du Redéploiement Industriel et du Commerce Extérieur, Ministère de la Recherche et de la Technologie, Centre de Prospective et d'Évaluation (Paris: April 1984a).

Bon F. and D. Boy, "Recherche sur les Attitudes de l'Opinion Publique à l'Égard de la Recherche Scientifique," Document No. 4 of *La Science, la Technique et l'Opinion Publique en 1982*, Fondation Nationale des Sciences Politiques, Paris, and Institut d'Études Politiques, Grenoble (April 1984b).

Boy D and G. Michelat, "Les Francais et les 'para-sciences'," *La Recherche* 161 (December 1984), pp. 1560-1567.

Greeley, A., "Mysticism Goes Mainstream," *American Health*, Vol. VI, No. 1 (January/February 1987), pp. 47-49.

Kuroda, Y., C. Hayashi, and T. Suzuki, "The Role of Language in Cross-National Surveys: American and Japanese Respondents," *Applied Stochastic Models and Data Analysis*, Vol. 2, pp. 43-59 (1986).

Market & Opinion Research International Limited (MORI), "Public Attitudes to New Technology: Research Study Conducted for the Technological Change Centre" (1985).

Miller, J.D., *The American People and Science Policy: The Role of Public Attitudes in the Policy Process* (New York: Pergamon Press, 1983a).

Miller, J.D., "A National Survey of Adult Attitudes Toward Science and Technology in the United States," report prepared by the Annenberg School of Communications, University of Pennsylvania (1983b).

Miller, J.D. "The American College Student: 1985," paper presented to the 1986 annual meeting of the American Educational Research Association, San Francisco, California (1986).

Miller, J.D., "The Impact of the Challenger Accident on Public Attitudes toward the Space Program," report to the National Science Foundation (January 1987).

Miller, J.D., *Public Attitudes Toward Science and Technology, 1985* (forthcoming 1988).

National Opinion Research Center, "The Attitudes of the U.S. Public Toward Science and Technology," final report to the National Science Foundation in accordance with Contract No. C-SRS-7816839 (July 1980).

National Science Board, *Science Indicators—1980* (Washington, DC: Government Printing Office, 1981).

National Science Board, *Science Indicators—1982* (Washington, DC: Government Printing Office, 1983).

National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1985).

Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (in Japanese, forthcoming 1988).

Rossini, F.A. and A.L. Porter, "The Use of Computers in Industrial Research and Development: An Analysis of the Industrial Research Institute Survey" (Georgia Institute of Technology, Office of Interdisciplinary Programs, 1985).

*Science*, "Science Sections in U.S. Newspapers Increase Dramatically in Past 2 Years," *Science* 235 (January 23, 1987).

Smith, T.W., "Can We Have Confidence in Confidence? Revisited," in U.S. Bureau of the Census, *Special Demographic Analyses, Measurement of Subjective Phenomena* (Washington, DC: Government Printing Office, 1981).

Vine, R.D., ed., *The Impact of Technological Change in the Industrial Democracies: Public Atitudes toward Information Technology* (Paris: The Atlantic Institute for International Affairs, 1985).

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## CHAPTER 8. PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

## Appendix table 1-1. Achievement scores in mathematics, by age, gender and ethnicity: 1977-86

| Gender and ethnicity | 1977/78 | 1981/82 | 1985/86 |
|---|---|---|---|
| | Nine year olds | | |
| Total | 54.1 | 54.7 | 55.4 |
| Male | 53.8 | 54.0 | 55.8 |
| Female | 54.4 | 55.3 | 55.1 |
| White | 57.0 | 57.3 | 58.5 |
| Black | 40.5 | 42.0 | 46.1 |
| Hispanic | 45.2 | 46.8 | 46.6 |
| | Thirteen year olds | | |
| Total | 62.7 | 65.2 | 63.8 |
| Male | 62.6 | 65.3 | 64.1 |
| Female | 62.7 | 65.1 | 63.4 |
| White | 65.9 | 68.0 | 66.3 |
| Black | 47.6 | 52.1 | 56.6 |
| Hispanic | 51.0 | 57.0 | 54.4 |
| | Seventeen year olds | | |
| Total | 62.9 | 62.1 | 62.9 |
| Male | 65 [illegible] | 63.9 | 64.5 |
| Female | 60.9 | 60.3 | 61.4 |
| White | 65.9 | 65.4 | 66.3 |
| Black | 44.7 | 45.2 | 48.1 |
| Hispanic | 48.7 | 47.6 | 51.0 |

SOURCE: Educational Testing Service. *National Assessment of Educational Progress*

See figure O-16 in Overview.

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## Appendix table 1-2. Achievement scores in science, by age, gender and ethnicity: 1977-86

| Gender and ethnicity | 1976/77 | 1981/82 | 1985/86 |
|---|---|---|---|
| | Nine year olds | | |
| Total | 54.4 | 57.7 | 58.8 |
| Male | 54.7 | 56.7 | 58.1 |
| Female | 54.1 | 58.6 | 59.5 |
| White | 57.5 | 60.5 | 62.0 |
| Black | 40.9 | 46.4 | 49.5 |
| Hispanic | 42.1 | 45.9 | 49.4 |
| | Thirteen year olds | | |
| Total | 54.5 | 54.8 | 55.1 |
| Male | 55.7 | 56.0 | 56.7 |
| Female | 53.4 | 53.1 | 53.5 |
| White | 57.2 | 56.9 | 57.6 |
| Black | 43.2 | 45.1 | 47.7 |
| Hispanic | 43.2 | 47.0 | 46.6 |
| | Seventeen year olds | | |
| Total | 71.3 | 68.8 | 71.5 |
| Male | 73.4 | 71.1 | 73.4 |
| Female | 69.2 | 66.7 | 69.6 |
| White | 73.7 | 71.7 | 74.5 |
| Black | 56.8 | 54.8 | 60.1 |
| Hispanic | 62.6 | 60.4 | 62.4 |

SOURCE: Educational Testing Service. *National Assessment of Educational Progress*

See figure O-17 in Overview.

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## Appendix table 1-3. Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by race and gender: 1975-86

| Race and gender | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SAT Verbal Scores[1] | | | | | | | | | | |
| All White students | 474 | 467 | 466 | 464 | 461 | 462 | 462 | 461 | 464 | 468 | 468 |
| White males | 470 | 463 | 463 | 461 | 458 | 461 | 461 | 460 | 465 | 468 | 469 |
| White females | 480 | 475 | 471 | 468 | 466 | 464 | 465 | 463 | 463 | 468 | 467 |
| All Black students | 361 | 352 | 354 | 349 | 351 | 352 | 361 | 357 | 357 | 363 | 363 |
| Black males | 358 | 352 | 356 | 351 | 353 | 355 | 364 | 360 | 360 | 367 | 368 |
| Black females | 365 | 351 | 351 | 347 | 349 | 349 | 357 | 354 | 354 | 358 | 357 |
| Other students | 433 | 414 | 406 | 402 | 403 | 400 | 400 | 359 | 397 | 403 | 403 |
| All students | 464 | 454 | 451 | 448 | 446 | 446 | 446 | 444 | 446 | 451 | 450 |
| | SAT Math Scores[1] | | | | | | | | | | |
| All White students | 530 | 528 | 524 | 521 | 521 | 520 | 522 | 523 | 525 | 527 | 527 |
| White males | 543 | 545 | 541 | 538 | 537 | 536 | 538 | 538 | 539 | 543 | 546 |
| White females | 505 | 498 | 494 | 493 | 495 | 494 | 495 | 497 | 501 | 501 | 496 |
| All Black students | 393 | 384 | 383 | 385 | 390 | 391 | 396 | 397 | 399 | 403 | 400 |
| Black males | 403 | 400 | 401 | 402 | 404 | 406 | 410 | 411 | 411 | 417 | 417 |
| Black females | 381 | 367 | 365 | 367 | 374 | 375 | 381 | 382 | 387 | 388 | 382 |
| Other students | 508 | 495 | 486 | 489 | 492 | 493 | 493 | 494 | 497 | 500 | 502 |
| All students | 520 | 514 | 509 | 507 | 507 | 507 | 508 | 509 | 511 | 514 | 513 |

[1] SAT scores range between a low of 200 and a high of 800.

SOURCE: Jenlee Grandy, "Ten-Year Trends in SAT Scores and other Characteristics of High School Seniors taking the SAT and Planning to Study Math, Science, or Engineering," unpublished report, Educational Testing Service (October 1987)

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## Appendix table 1-4. Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by major discipline: 1975-86

| Intended Major Field | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SAT Verbal Scores[1] | | | | | | | | | | |
| Math & statistics | 465 | 464 | 464 | 459 | 455 | 456 | 455 | 452 | 457 | 459 | 469 |
| Computer science | 439 | 439 | 436 | 432 | 429 | 427 | 426 | 422 | 420 | 423 | 413 |
| Physical sciences | 520 | 518 | 517 | 516 | 512 | 515 | 514 | 513 | 514 | 521 | 526 |
| Architecture/environmental engineering | 432 | 424 | 423 | 418 | 415 | 414 | 413 | 412 | 415 | 427 | 419 |
| Engineering | 453 | 451 | 450 | 448 | 446 | 448 | 451 | 450 | 455 | 456 | 455 |
| Life sciences | 468 | 461 | 460 | 457 | 453 | 455 | 456 | 457 | 462 | 467 | 464 |
| Earth & environmental sciences | 454 | 457 | 456 | 453 | 451 | 451 | 449 | 451 | 454 | 457 | 458 |
| Psychology | 451 | 444 | 439 | 435 | 434 | 433 | 435 | 437 | 436 | 440 | 441 |
| Social sciences | 476 | 449 | 443 | 443 | 445 | 446 | 453 | 454 | 457 | 461 | 453 |
| Interdisciplinary/other sciences | 499 | 515 | 512 | 509 | 506 | 510 | 507 | 503 | 509 | 507 | 520 |
| Total Science, Math & Engineering | 464 | 454 | 451 | 448 | 446 | 446 | 446 | 444 | 446 | 451 | 450 |
| | SAT Math Scores[1] | | | | | | | | | | |
| Math & statistics | 584 | 588 | 585 | 580 | 577 | 572 | 569 | 572 | 578 | 578 | 593 |
| Computer science | 524 | 529 | 522 | 517 | 513 | 502 | 497 | 497 | 496 | 501 | 489 |
| Physical sciences | 592 | 595 | 590 | 586 | 585 | 580 | 582 | 583 | 583 | 587 | 598 |
| Architecture/environmental engineering | 509 | 506 | 501 | 496 | 494 | 489 | 487 | 486 | 486 | 491 | 494 |
| Engineering | 546 | 550 | 543 | 540 | 538 | 537 | 540 | 543 | 546 | 548 | 553 |
| Life sciences | 509 | 500 | 496 | 493 | 490 | 489 | 489 | 491 | 499 | 505 | 504 |
| Earth & environmental sciences | 500 | 501 | 495 | 490 | 489 | 486 | 485 | 485 | 485 | 487 | 489 |
| Psychology | 461 | 455 | 449 | 447 | 447 | 447 | 446 | 449 | 453 | 455 | 455 |
| Social sciences | 495 | 465 | 456 | 457 | 460 | 461 | 464 | 468 | 470 | 475 | 469 |
| Interdisciplinary/other sciences | 569 | 593 | 585 | 578 | 574 | 575 | 572 | 572 | 575 | 575 | 589 |
| Total Science, Math & Engineering | 520 | 514 | 509 | 507 | 507 | 507 | 508 | 509 | 511 | 514 | 513 |

[1] SAT scores range between a low of 200 and a high of 800.

SOURCE: Jenlee Grandy, "Ten-Year Trends in SAT Scores and other Characteristics of High School Seniors taking the SAT and Planning to Study Math, Science, or Engineering," unpublished report, Educational Testing Service (October 1987)

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**Appendix table 1-5. Average scores on the Scholastic Aptitude Test for college-bound high school seniors by ethnic group and gender: 1976-87**

| Ethnic group and gender | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1987 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SAT Verbal Scores[1] | | | | | | | | | | |
| All students | 431 | 429 | 429 | 427 | 727 | 727 | 726 | 725 | 726 | 431 | 430 |
| Men | 433 | 431 | 433 | 431 | 428 | 430 | 431 | 430 | 433 | 437 | 435 |
| Women | 430 | 427 | 425 | 423 | 420 | 418 | 421 | 420 | 420 | 425 | 425 |
| Native American | 388 | 390 | 387 | 386 | 390 | 391 | 388 | 388 | 390 | 392 | 393 |
| Asian-American | 414 | 405 | 401 | 396 | 396 | 397 | 398 | 395 | 398 | 404 | 405 |
| Black | 332 | 330 | 332 | 330 | 330 | 332 | 341 | 339 | 342 | 346 | 351 |
| Mexican-American | 371 | 370 | 370 | 370 | 372 | 373 | 377 | 375 | 376 | 382 | 379 |
| Puerto Rican | 364 | 355 | 349 | 345 | 350 | 353 | 360 | 358 | 358 | 368 | 360 |
| Other Hispanic | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 387 |
| White | 451 | 448 | 446 | 444 | 442 | 442 | 444 | 443 | 445 | 449 | 447 |
| Other | 410 | 402 | 399 | 393 | 394 | 388 | 392 | 386 | 388 | 391 | 405 |
| | SAT Math Scores[1] | | | | | | | | | | |
| All students | 472 | 470 | 468 | 467 | 466 | 466 | 467 | 468 | 471 | 475 | 476 |
| Men | 497 | 497 | 494 | 493 | 491 | 492 | 493 | 493 | 495 | 499 | 500 |
| Women | 446 | 445 | 444 | 443 | 443 | 443 | 443 | 445 | 449 | 452 | 453 |
| Native American | 420 | 421 | 419 | 421 | 426 | 425 | 424 | 425 | 427 | 428 | 432 |
| Asian-American | 518 | 514 | 510 | 511 | 509 | 513 | 513 | 514 | 519 | 518 | 521 |
| Black | 354 | 357 | 354 | 358 | 390 | 362 | 366 | 369 | 373 | 376 | 377 |
| Mexican-American | 410 | 408 | 402 | 410 | 413 | 415 | 416 | 417 | 420 | 426 | 424 |
| Puerto Rican | 401 | 397 | 388 | 388 | 394 | 398 | 403 | 403 | 405 | 409 | 400 |
| Other Hispanic | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 432 |
| White | 493 | 489 | 485 | 483 | 482 | 483 | 483 | 484 | 487 | 190 | 489 |
| Other | 458 | 457 | 450 | 447 | 449 | 447 | 449 | 446 | 450 | 448 | 455 |

[1] SAT scores range between a low of 200 and a high of 800.

Note: NA = Not Available.

Note: SAT scores by ethnic group were not available for 1986.

SOURCE: Educational Testing Service, *1987 Profile of SAT and Achievement Test Takers. National Report*, College Entrance Examination Board, 1987.

See figures 1-1 and 1-3.

## Appendix table 1-6. Average achievement scores in functions and calculus, highest-scoring one percent and five percent and all students, 12th grade college preparatory mathematics students, by country: 1981/2

| Country | Top one percent | Top five percent | All students |
|---|---|---|---|
| | Average scores | | |
| Hungary | 66.0 | 58.0 | 42.0 |
| Canada (B.C.) | 58.0 | 52.0 | 39.0 |
| Canada (Ontario) | 67.0 | 58.5 | 49.5 |
| Scotland | 61.0 | 54.0 | 45.0 |
| Finland | 68.0 | 62.0 | 53.0 |
| United States | 61.0 | 52.0 | 43.0 |
| Sweden | 67.0 | 59.0 | 52.0 |
| Japan | 70.0 | 67.0 | 58.0 |
| New Zealand | 66.0 | 58.0 | 52.0 |
| Belgium (Flemish) | 63.0 | 56.0 | 50.0 |
| Belgium (French) | 62.0 | 55.0 | 48.0 |
| England/Wales | 65.0 | 57.0 | 55.0 |
| Israel | 61.0 | 50.0 | 48.0 |

Note: Countries are arranged in decreasing order in terms of the proportion of students enrolled in advanced mathematics programs.

SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois, Stipes Publishing Company (January, 1987). p. 26

See figure O-15 in Overview.

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## Appendix table 1-7. Distribution by intended major field of students receiving highest scores[1] on the SAT mathematics test: 1975-86

| Intended Major Field | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | | | | | |
| All fields | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Total science, mathematics & engineering | 44.9 | 40.4 | 44.0 | 46.0 | 45.5 | 46.6 | 50.4 | 48.8 | 46.0 | 46.1 | 43.9 |
| Total science & math | 32.8 | 25.4 | 26.1 | 26.7 | 24.8 | 25.5 | 27.1 | 26.9 | 25.2 | 25.2 | 22.2 |
| Math & statistics | 6.6 | 4.8 | 4.7 | 4.1 | 3.6 | 3.5 | 3.2 | 3.1 | 3.3 | 3.5 | 2.8 |
| Computer science | 2.0 | 2.7 | 3.7 | 4.8 | 5.4 | 6.9 | 8.9 | 10.0 | 8.5 | 6.7 | 4.2 |
| Physical sciences | 2.1 | 3.2 | 3.4 | 3.4 | 3.4 | 3.0 | 3.0 | 2.8 | 2.7 | 2.9 | 2.[illegible] |
| Life sciences | 10.8 | 5.4 | 5.3 | 5.1 | 4.4 | 4.4 | 4.4 | 4.1 | 4.2 | 4.4 | 4.6 |
| Earth & environmental sciences | 0.8 | 1.1 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.5 | 0.6 |
| Psychology | 2.3 | 2.0 | 2.1 | 2.4 | 2.0 | 2.1 | 2.1 | 1.9 | 1.9 | 2.4 | 2.3 |
| Social sciences | 4.4 | 4.3 | 3.9 | 4.1 | 3.7 | 3.5 | 3.5 | 3.3 | 3.2 | 3.8 | 4.1 |
| Interdisciplinary/other sciences | 3.8 | 1.8 | 1.9 | 1.8 | 1.5 | 1.4 | 1.3 | 1.1 | 1.0 | 1.0 | 0.7 |
| Total engineering | 12.2 | 15.0 | 17.9 | 19.4 | 20.7 | 21.1 | 23.3 | 21.9 | 20.8 | 20.9 | 21.8 |
| Architecture/environmental engineering | 1.8 | 1.5 | 1.7 | 1.8 | 1.7 | 1.6 | 1.5 | 1.1 | 1.0 | 1.2 | 1.3 |
| Engineering | 10.4 | 13.5 | 16.2 | 17.6 | 19.0 | 19.5 | 21.8 | 20.8 | 19.8 | 19.8 | 20.5 |
| Non-S/E major fields | 55.1 | 59.6 | 59.0 | 54.0 | 54.5 | 53.4 | 49.6 | 51.2 | 53.9 | 53.9 | 56.1 |
| Humanities | 2.3 | 1.9 | 1.9 | 2.1 | 1.9 | 1.9 | 2.0 | 1.7 | 1.7 | 2.0 | 1.8 |
| Pre-medicine | 5.3 | 7.8 | 7.8 | 8.0 | 7.8 | 8.1 | 8.1 | 8.0 | 8.1 | 8.5 | 7.4 |
| Pre-law | — | 2.3 | 4.0 | 3.9 | 3.3 | 3.4 | 3.4 | 3.1 | 2.9 | 3.1 | 2.6 |
| Business | 5.1 | 6.7 | 8.0 | 9.7 | 8.9 | 9.2 | 9.5 | 8.5 | 8.3 | 10.3 | 10.9 |
| Other non-S/E fields | 42.5 | 41.0 | 34.4 | 30.3 | 32.7 | 30.8 | 26.6 | 29.9 | 32.9 | 30.0 | 33.4 |

[1] Students scoring higher than the 90th percentile in their ethnic/gender group

SOURCE: Jenlee Grandy, "Trends in the Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," Educational Testing Service, Final Report to the National Science Foundation (March 30, 1987)

See figure 1-6.

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**Appendix table 1-8. 90th percentile scores on the Scholastic Aptitude Tests for high school students intending to major in science and engineering, by race and gender: 1975-86**

| Race and gender | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SAT Verbal Scores[1] | | | | | | | | | | |
| White males | 590 | 585 | 587 | 587 | 581 | 583 | 584 | 582 | 590 | 592 | 593 |
| White females | 580 | 582 | 580 | 579 | 575 | 573 | 576 | 573 | 573 | 579 | 581 |
| Black males | 485 | 482 | 477 | 474 | 476 | 481 | 487 | 486 | 489 | 491 | 497 |
| Black females | 463 | 465 | 462 | 458 | 461 | 460 | 472 | 470 | 467 | 474 | 482 |
| Other students | 578 | 565 | 558 | 558 | 553 | 549 | 553 | 549 | 561 | 571 | 560 |
| All students | 580 | 577 | 575 | 576 | 571 | 570 | 572 | 570 | 574 | 579 | 579 |
| | SAT Math Scores[1] | | | | | | | | | | |
| White males | 658 | 663 | 660 | 658 | 657 | 655 | 657 | 662 | 662 | 663 | 672 |
| White females | 603 | 605 | 602 | 599 | 601 | 596 | 599 | 605 | 610 | 610 | 615 |
| Black males | 523 | 532 | 525 | 522 | 521 | 531 | 535 | 534 | 539 | 547 | 549 |
| Black females | 475 | 479 | 470 | 468 | 471 | 486 | 483 | 485 | 491 | 497 | 495 |
| Other students | 630 | 625 | 621 | 626 | 626 | 625 | 627 | 634 | 642 | 645 | 650 |
| All students | 626 | 628 | 625 | 628 | 625 | 623 | 625 | 632 | 635 | 637 | 642 |

[1] SAT scores range between a low of 200 and a high of 800.

SOURCE: Jerilee Grandy, "Trends in the Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," Educational Testing Service, Final Report to the National Science Foundation (March 30, 1987)

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Appendix table 1-9. Percentage distribution of freshmen by probable major field of study in all institutions of higher education: 1975-85

| Probable major field of study | 1975 | | 1978 | | 1980 | | 1982 | | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | Women | Men | Women | Men | Women | Men | Women | Men | Women | Men | Women | Men | Women |
| | Percent in each field | | | | | | | | | | | | | |
| Agriculture/forestry | 5.7 | 1.9 | 4.5 | 2.0 | 4.1 | 1.8 | 3.8 | 1.4 | 2.9 | 0.9 | 3.3 | 1.0 | 3.3 | 1.0 |
| Arts/humanities | 12.7 | 12.8 | 7.4 | 10.6 | 6.4 | 10.1 | 6.8 | 9.7 | 6.8 | 9.0 | 6.6 | 8.8 | 7.1 | 8.8 |
| Biological Sciences | 7.1 | 5.5 | 4.8 | 4.4 | 3.7 | 3.8 | 3.7 | 3.8 | 4.1 | 3.4 | 4.1 | 4.2 | 3.4 | 3.3 |
| Business | 20.1 | 17.5 | 25.0 | 23.1 | 22.9 | 24.5 | 22.3 | 25.7 | 22.7 | 26.0 | 25.1 | 27.5 | 25.7 | 27.5 |
| Education | 4.6 | 15.5 | 3.3 | 12.1 | 3.3 | 11.6 | 2.4 | 9.0 | 2.9 | 8.9 | 2.8 | 9.6 | 3.3 | 10.4 |
| Engineering | 14.0 | 1.3 | 18.8 | 2.3 | 21.0 | 3.2 | 22.3 | 3.6 | 20.6 | 3.5 | 20.1 | 3.0 | 19.3 | 3.0 |
| Health professions (Non-MD) | 1.8 | 13.2 | 2.0 | 14.6 | 1.9 | 13.3 | 1.6 | 17.8 | 2.1 | 14.9 | 2.3 | 13.8 | 2.0 | 11.6 |
| Mathematics/statistics | 1.1 | 1.1 | 1.1 | 0.8 | 0.7 | 0.6 | 0.6 | 0.7 | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | 0.8 |
| Computer science | NA | NA | 1.6 | 1.2 | 2.7 | 2.4 | 4.9 | 4.0 | 5.4 | 3.7 | 4.3 | 2.7 | 3.1 | 1.6 |
| Physical sciences | 4.0 | 1.3 | 3.5 | 1.3 | 3.6 | 1.6 | 2.6 | 1.0 | 2.5 | 1.0 | 2.5 | 1.1 | 2.3 | 0.9 |
| Premed/predent/prevet | NA | NA | 4.0 | 2.9 | 3.6 | 3.2 | 3.2 | 3.0 | 3.3 | 3.2 | 3.2 | 3.1 | 3.1 | 3.2 |
| Social sciences | 3.7 | 8.9 | 5.0 | 9.5 | 4.5 | 8.6 | 4.2 | 7.2 | 4.2 | 7.6 | 5.1 | 8.4 | 5.2 | 9.6 |
| Other fields (tech) | 10.3 | 6.7 | 7.0 | 2.0 | 8.5 | 2.9 | 9.7 | 4.3 | 9.9 | 3.8 | 7.7 | 2.4 | 7.5 | 2.4 |
| Other fields (non-tech) | 10.2 | 8.8 | 8.1 | 7.9 | 9.3 | 6.9 | 8.2 | 3.3 | 8.1 | 7.1 | 8.0 | 7.6 | 9.0 | 8.1 |
| Undecided | 4.6 | 5.5 | 3.9 | 5.3 | 3.8 | 5.5 | 3.7 | 5.5 | 4.0 | 5.7 | 4.1 | 6.2 | 4.7 | 6.9 |

Note: Totals may not equal 100% due to rounding.

SOURCE: Cooperative Institutional Research Program, *The American Freshman: National Norms for Fall 1985*, and reports with the same title for 1971-1984, University of California at Los Angeles and American Council on Education (December, 1985)

See figure 1-7.

### Appendix table 1-10. Earnings of individuals in teaching and in other selected occupations by gender: 1961 and 1981

| Occupation in longest job held during the year | Men | | Women | |
|---|---|---|---|---|
| | 1961 | 1981 | 1961 | 1981 |
| | Average annual salaries | | | |
| All full-time workers | 17,010 | 20,260 | 10,078 | 12,001 |
| Salaried professional, total | 22,437 | 25,350 | 14,903 | 15,631 |
| Accountants | NA | 24,[illegible] | NA | 15,558 |
| Health workers (except physicians and dentists) | NA | 16,631 | NA | 16,827 |
| Teachers (elementary and secondary schools) | 19,792 | 20,249 | 15,888 | 16,056 |
| Managers and administrators | 21,211 | 25,425 | 10,370 | 14,820 |
| Sales workers | 18,305 | 22,331 | 7,269 | 11,238 |
| Clerical workers | 16,280 | 18,938 | 11,306 | 11,238 |
| Craft workers | 18,256 | 20,095 | NA | 12,904 |
| Factory workers | 15,657 | 16,948 | 8,972 | 10,301 |

NA = Not Available.

Note: These figures reflect occupational categories used by the Bureau of the Census up until 1981.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Population Reports: Money Income of Households, Families, and Persons in the United States*, Series P-60, Nos. 39 and 137

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### Appendix table 1-11. Distribution of elementary and secondary science and mathematics teachers by gender, for various grade levels: 1977 and 1985/86

| Course and gender | 1977 | | | | 1985/86 | | | |
|---|---|---|---|---|---|---|---|---|
| | Grade level | | | | Grade level | | | |
| | K-3 | 4-6 | 7-9 | 10-12 | K-3 | 4-6 | 7-9 | 10-12 |
| | Percent | | | | | | | |
| Mathematics | | | | | | | | |
| Male | 6 | 21 | 54 | 68 | 4 | 20 | 45 | 53 |
| Female | 94 | 76 | 46 | 32 | 93 | 79 | 51 | 46 |
| Unknown | 0 | 2 | 0 | 0 | 1 | 1 | 4 | 1 |
| Science | | | | | | | | |
| Male | 2 | 33 | 62 | 74 | 3 | 23 | 56 | 68 |
| Female | 98 | 67 | 38 | 24 | 94 | 76 | 41 | 31 |
| Unknown | 0 | 0 | 0 | 0 | 3 | 1 | 3 | 1 |

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Education*

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## Appendix table 1-12. Distribution of elementary and secondary science and mathematics teachers by race, for various grade levels: 1985/86

| Course and grade level | Ethnicity/Race | | | | | |
|---|---|---|---|---|---|---|
| | White | Black | Hispanic | American Indian, Alaskan Native | Asian or Pacific Islander | Unknown |
| Mathematics | | | | | | |
| K-3 | 84 | 10 | 1 | 0 | 0 | 4 |
| 4-6 | 84 | 10 | 2 | 0 | 0 | 2 |
| 7-9 | 90 | 6 | 1 | 0 | 1 | 3 |
| 10-12 | 94 | 3 | 1 | 0 | 1 | 1 |
| Science | | | | | | |
| K-3 | | | | | | |
| 4-6 | 82 | 9 | 4 | 0 | 1 | 4 |
| 7-9 | 86 | 8 | 4 | 0 | 1 | 1 |
| 10-12 | 88 | 6 | 1 | 0 | 1 | 4 |

SOURCE: Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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## Appendix table 1-13. Percent of elementary-school science teachers who have completed various college courses, by grade level taught: 1985/86

| Courses | Grade level taught | |
|---|---|---|
| | K-3 | 4-6 |
| | — Percent — | |
| Education | | |
| General methods of teaching | 95 | 95 |
| Methods of teaching elementary school science | 87 | 88 |
| Methods of teaching middle school science | 7 | 20 |
| Supervised student teaching | 77 | 87 |
| Psychology, human development | 83 | 88 |
| Computing | | |
| Instructional uses of computers | 31 | 37 |
| Computer programming | 11 | 21 |
| Sciences | | |
| Biology, environmental, life sciences | 83 | 87 |
| Chemistry | 30 | 37 |
| Physics | 17 | 21 |
| Physical science | 58 | 61 |
| Earth/space science | 39 | 51 |
| No science course | 5 | 5 |
| One type of science course | 18 | 12 |
| Biology | 15 | 8 |
| Physical science | 2 | 3 |
| Earth/space science | 1 | 1 |
| Two types of science courses | 40 | 40 |
| Biology and physical science | 34 | 31 |
| Biology and earth/space science | 5 | 6 |
| Physical science and earth/space science | 1 | 3 |
| All three categories of science courses | 31 | 42 |
| Unknown | 4 | 2 |

SOURCE: Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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**Appendix table 1-14. Percent distribution of secondary-school science teachers, by grade level and number of college courses completed in science, calculus, and computer science: 1985/86**

| Number of courses completed | Life science | | Chemistry | | Physics | | Earth science | | Calculus | | Computer science | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grade level taught | | | | | | | | | | | |
| | 7-9 | 10-12 | 7-9 | 10-12 | 7-9 | 10-12 | 7-9 | 10-12 | 7-9 | 10-12 | 7-9 | 10-12 |
| | Percent | | | | | | | | | | | |
| 0 | 3 | 7 | 18 | 6 | 16 | 13 | 24 | 27 | 53 | 44 | 52 | 57 |
| 1 | 6 | 7 | 12 | 8 | 23 | 17 | 20 | 21 | 20 | 19 | 24 | 21 |
| 2 | 12 | 6 | 16 | 14 | 21 | 23 | 16 | 17 | 12 | 16 | 12 | 10 |
| 3 | 5 | 5 | 13 | 14 | 15 | 12 | 9 | 9 | 7 | 9 | 4 | 5 |
| 4 | 11 | 5 | 12 | 14 | 7 | 10 | 6 | 6 | 2 | 5 | 2 | 3 |
| 5 | 7 | 3 | 8 | 9 | 3 | 4 | 6 | 3 | 1 | 2 | 1 | 1 |
| 6 | 5 | 3 | 6 | 7 | 6 | 5 | 3 | 3 | 0 | 1 | 0 | 0 |
| 7 | 4 | 3 | 2 | 3 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 8 | 46 | 60 | 10 | [illegible] | 7 | 15 | 12 | 6 | 0 | 2 | 1 | 2 |
| Unknown | 2 | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 4 | 1 | 3 | 1 |

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Education*

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**Appendix table 1-15. Percent of secondary-school science teachers who have completed various college courses, by grade level taught: 1985/86**

| Courses | Grade level taught 7-9 | 10-12 |
|---|---|---|
| | —— Percent —— | |
| Education | | |
| General methods of teaching | 94 | 94 |
| Methods of teaching secondary school science | 61 | 82 |
| Methods of teaching middle school science | 30 | 20 |
| Supervised student teaching | 83 | 79 |
| Psychology, human development | 85 | 87 |
| Instructional uses of computers | 33 | 30 |
| Mathematics/computer science | | |
| College algebra, trigonometry, elementary functions | 75 | 78 |
| Calculus | 41 | 53 |
| Differential equations | 16 | 25 |
| Probability and statistics | 44 | 44 |
| Computer programming | 33 | 33 |
| Life sciences | | |
| Introductory biology | 91 | 85 |
| Botany, plant physiology, etc. | 70 | 73 |
| Cell biology | 54 | 58 |
| Ecology, environmental science | 62 | 63 |
| Genetics, evolution | 55 | 64 |
| Microbiology | 48 | 53 |
| Physiology | 63 | 65 |
| Zoology, animal behavior, etc. | 64 | 71 |
| Chemistry | | |
| General chemistry | 76 | 92 |
| Analytical chemistry | 30 | 47 |
| Organic chemistry | 51 | 70 |
| Physical chemistry | 21 | 32 |
| Biochemistry | 25 | 34 |
| Physics | | |
| General physics | 73 | 81 |
| Electricity and magnetism | 18 | 28 |
| Heat and thermodynamics | 16 | 24 |
| Mechanics | 15 | 26 |
| Modern or nuclear physics | 12 | 23 |
| Optics | 11 | 18 |
| Earth/space sciences | | |
| Astronomy | 40 | 36 |
| Geology | 56 | 49 |
| Meteorology | 27 | 20 |
| Oceanography | 26 | 19 |
| Physical geography | 39 | 25 |
| Other | | |
| History of science | 21 | 23 |
| Science and society | 18 | 16 |
| Engineering | 8 | 12 |

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Education*

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## Appendix table 1-16. Percent of elementary-school mathematics teachers who have completed various college courses, by grade level taught: 1985/86

| Courses | Grade level taught | |
|---|---|---|
| | K-3 | 4-6 |
| | —— Percent —— | |
| **Education** | | |
| General methods of teaching | 94 | 93 |
| Methods of teaching elementary school mathematics | 90 | 90 |
| Methods of teaching middle school mathematics | 14 | 27 |
| Supervised student teaching | 82 | 83 |
| Psychology, human development | 83 | 87 |
| Instructional uses of computers | 30 | 34 |
| **Mathematics/Computer science** | | |
| Computer programming | 17 | 24 |
| Mathematics for elementary school teachers | 89 | 90 |
| Mathematics for secondary school teachers | 11 | 21 |
| Geometry for elementary or middle school teachers | 17 | 21 |
| College algebra, trigonometry, elementary functions | 30 | 37 |
| Calculus | 8 | 12 |
| Upper division geometry | 5 | 7 |
| Probability and statistics | 21 | 27 |

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Education*

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## Appendix table 1-17. Percent of secondary-school mathematics teachers who have completed various courses, by grade level taught: 1985

| Courses | Grade level taught | |
|---|---|---|
| | 7-9 | 10-12 |
| | —Percent— | |
| **Education** | | |
| General methods of teaching | 90 | 93 |
| Methods of teaching secondary school mathematics | 53 | 80 |
| Methods of teaching middle school mathematics | 37 | 25 |
| Supervised student teaching | 79 | 81 |
| Psychology, human development | 84 | 87 |
| Institutional uses of computers | 40 | 42 |
| **Mathematics/Computer science** | | |
| College algebra, trigonometry, elem. functions | 80 | 87 |
| Calculus | 67 | 89 |
| Advanced calculus | 39 | 63 |
| Differential equations | 39 | 61 |
| Geometry | 67 | 80 |
| Probability and statistics | 59 | 76 |
| Abstract algebra/number theory | 48 | 69 |
| Applications of mathematics/problem solving | 34 | 39 |
| History of mathematics | 26 | 37 |
| Other upper division mathematics | 37 | 63 |
| Computer programming | 46 | 64 |

SOURCE: Research Triangle Institute, *1985 National Survey of Science and Mathematics Education*

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### Appendix table 1-18. Percent of secondary science and mathematics teachers who feel inadequately qualified to teach one or more of their courses: 1977 and 1985/86

| Subject and grade level | 1977 | 1985/86 |
|---|---|---|
| | Percent | |
| Science | | |
| Grades 7-9 | 13 | 7 |
| Grades 10-12 | 13 | 7 |
| Mathematics | | |
| Grades 7-9 | 11 | 9 |
| Grades 10-12 | 5 | 5 |

SOURCE: Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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### Appendix table 1-19. Percent of elementary- and secondary-school science and mathematics teachers, by year in which they most recently took a college course in the subject they teach: 1985/86

| | Science | | | Mathematics | | |
|---|---|---|---|---|---|---|
| | Grade level | | | Grade level | | |
| Last course taken | K–6 | 7–9 | 10–12 | K–6 | 7–9 | 10–12 |
| | Percent | | | | | |
| Prior to 1975 | 39 | 18 | 20 | 36 | 27 | 25 |
| 1975 to 1982 | 31 | 28 | 31 | 29 | 31 | 32 |
| 1983 or later | 16 | 47 | 46 | 24 | 34 | 38 |
| Unknown | 13 | 7 | 3 | 10 | 8 | 5 |

SOURCE: Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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### Appendix table 1-20. Percent of elementary- and secondary-school science and mathematics teachers, by time spent in in-service education during the last 12 months: 1985/86

| | Science | | | Mathematics | | |
|---|---|---|---|---|---|---|
| Time spent in in-service education in the last 12 months | Grade level taught | | | Grade level taught | | |
| | K-6 | 7-9 | 10-12 | K-6 | 7-9 | 10-12 |
| | Percent | | | | | |
| None | 52 | 31 | 28 | 41 | 31 | 35 |
| Less than 6 hours | 23 | 22 | 22 | 31 | 26 | 18 |
| 6-15 hours | 13 | 23 | 25 | 16 | 22 | 21 |
| 16-35 hours | 4 | 10 | 12 | 5 | 11 | 13 |
| More than 35 hours | 3 | 10 | 12 | 3 | 8 | 10 |
| Unknown | 5 | 2 | 1 | 5 | 3 | 2 |

SOURCE. Research Triangle Institute. *1985 National Survey of Science and Mathematics Education*

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## Appendix table 1-21. Supply of new teacher graduates, with alternative projections: 1970-92

| Fall of year | | | |
|---|---|---|---|
| | Thousands | | |
| 1970 | 284 | | |
| 1971 | 314 | | |
| 1972 | 317 | | |
| 1973 | 313 | | |
| 1974 | 279 | | |
| 1975 | 238 | | |
| 1976 | 222 | | |
| 1977 | 194 | | |
| 1978 | 181 | | |
| 1979 | 163 | | |
| 1980 | 144 | | |
| 1981 | 141 | | |
| 1982 | 143 | | |
| 1983 | 146 | | |
| | Alternate Projections | | |
| | Low | Intermediate | High |
| | Thousands | | |
| 1984 | 126 | 146 | 160 |
| 1985 | 121 | 146 | 163 |
| 1986 | 115 | 144 | 165 |
| 1987 | 110 | 142 | 168 |
| 1988 | 107 | 139 | 171 |
| 1989 | 105 | 139 | 176 |
| 1990 | 102 | 139 | 181 |
| 1991 | 100 | 138 | 184 |
| 1992 | 99 | 137 | 188 |

SOURCE: U.S Department of Education. Center for Education Statistics, *The Condition of Education*, 1984 Edition (NCES 84-401), p 36

See figure 1-9



## Appendix table 1-22. Demand for new classroom teachers in elementary and secondary schools: 1970-92

| Fall of year | Total | Elementary schools | Secondary schools |
|---|---|---|---|
| | Thousands | | |
| 1970 | 208 | 115 | 93 |
| 1971 | 163 | 71 | 82 |
| 1972 | 179 | 107 | 72 |
| 1973 | 175 | 89 | 86 |
| 1974 | 183 | 103 | 80 |
| 1975 | 186 | 101 | 85 |
| 1976 | 150 | 78 | 72 |
| 1977 | 181 | 107 | 74 |
| 1978 | 138 | 82 | 56 |
| 1979 | 129 | 85 | 44 |
| 1980 | 127 | 69 | 58 |
| 1981 | 110 | 66 | 44 |
| 1982 | 143 | 94 | 49 |
| 1983 | 148 | 82 | 66 |
| 1984 | 142 | 78 | 64 |
| 1985 | 157 | 95 | 62 |
| 1986 | 170 | 114 | 56 |
| 1987 | 160 | 114 | 46 |
| 1988 | 164 | 126 | 38 |
| 1989 | 173 | 126 | 47 |
| 1990 | 183 | 131 | 52 |
| 1991 | 195 | 129 | 66 |
| 1992 | 209 | 129 | 80 |

Note: Data for 1970-82 are actual new hires. Data for 1983-92 are the intermediate value of three alternative projections (low, intermediate, and high).

SOURCE: U.S. Department of Education, Center for Education Statistics, *The Condition of Education*, 1984 Edition (NCES 84-401), p 36

See figure 1-9.

## Appendix table 1-23. Actual and projected public school enrollment:[1] 1970-92

| Fall of year | Thousands |
|---|---|
| 1970 | 45,909 |
| 1971 | 46,081 |
| 1972 | 45,744 |
| 1973 | 45,429 |
| 1974 | 45,053 |
| 1975 | 44,791 |
| 1976 | 44,317 |
| 1977 | 43,577 |
| 1978 | 42,550 |
| 1979 | 41,645 |
| 1980 | 40,987 |
| 1981 | 40,099 |
| 1982 | 39,652 |
| 1983 | 39,352 |
| 1984 | 39,293 |
| 1985 | 39,513 |
| 1986[2] | 39,712 |
| 1987[2] | 39,916 |
| 1988[2] | 40,116 |
| 1989[2] | 40,379 |
| 1990[2] | 40,898 |
| 1991[2] | 41,548 |
| 1992[2] | 42,259 |

[1] Includes most kindergarten and some nursery school enrollment.

[2] Estimated.

SOURCE: U.S. Department of Education, Center for Education Statistics, *Public and Private Elementary and Secondary Enrollments: Outlook to the Year 2000* (1987)

See figure 1-9. Science & Engineering Indicators—1987

## Appendix table 1-24. States which have enacted testing for initial certification of teachers: 1986

| State | Enacted | Year effective | Test Used[1] |
|---|---|---|---|
| Alabama | 1980 | 1981 | State |
| Arizona | 1980 | 1980 | State |
| Arkansas | 1979 | 1983 | NTE |
| California | 1981 | 1982 | State |
| Colorado | 1981 | 1983 | CAT |
| Connecticut | 1982 | 1985 | State |
| Delaware | 1982 | 1983 | PPST |
| Florida | 1978 | 1980 | State |
| Georgia | 1975 | 1980 | State |
| Hawaii | 1986 | 1986 | NTE |
| Illinois | 1985 | 1988 | State |
| Indiana | 1984 | 1985 | NTE |
| Kansas | 1984 | 1986 | (2) |
| Kentucky | 1984 | 1985 | NTE |
| Louisiana | 1977 | 1978 | NTE |
| Maine | 1984 | 1988 | NTE |
| Massachusetts | 1985 | (2) | (2) |
| Mississippi | 1975 | 1977 | NTE |
| Missouri | 1985 | 1988 | (2) |
| Montana | 1985 | 1986 | (2) |
| Nebraska | 1984 | 1989 | (2) |
| New Hampshire | 1984 | 1985 | NTE |
| New Jersey | 1984 | 1985 | NTE |
| New Mexico | 1981 | 1983 | NTE |
| New York | 1980 | 1984 | NTE |
| North Carolina | 1964 | 1964 | NTE |
| Oklahoma | 1980 | 1982 | State |
| Oregon | 1984 | 1985 | CBEST |
| South Carolina | 1979 | 1982 | NTE and State |
| South Dakota | 1985 | 1986 | NTE |
| Tennessee | 1980 | 1981 | NTE |
| Texas | 1981 | 1986 | State |
| Virginia | 1979 | 1980 | NTE |
| Washington | 1984 | (2) | (2) |
| West Virginia | 1982 | 1985 | State |

[1] Tests: CAT = California Achievement Test; CBEST = California Basic Educational Skills Test; NTE = National Teacher Exam; PPST = Pre-professional Skills Test; State = State developed test.

[2] To be determined.

SOURCE: Educational Commission of the States. *Clearinghouse Notes*, November 1985

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**Appendix table 1-25. State-required Carnegie units (1-year courses) for high school graduation for language arts, social studies, mathematics, and science: 1958-86**

| Year | Mathematics | | Science | |
|---|---|---|---|---|
| | Mean units required | Number of states requiring | Mean units required | Number of states requiring |
| 1958 | 1.1 | 31 | 1.2 | 31 |
| 1974 | 1.3 | 36 | 1.2 | 35 |
| 1980 | 1.3 | 35 | 1.2 | 35 |
| 1983 | 1.9 | 38 | 1.7 | 38 |
| 1984 | 2.1 | 44 | 1.9 | 44 |
| 1985 | 2.2 | 44 | 1.9 | 44 |
| 1986 | 2.3 | 45 | 1.9 | 45 |

| Year | Language Arts | | Social studies | |
|---|---|---|---|---|
| | Mean units required | Number of states requiring | Mean units required | Number of states requiring |
| 1958 | 3.4 | 37 | 1.9 | 44 |
| 1974 | 3.4 | 40 | 2.0 | 45 |
| 1980 | 3.4 | 39 | 2.0 | 42 |
| 1983 | 3.6 | 41 | 2.1 | 44 |
| 1984 | 3.8 | 45 | 2.4 | 49 |
| 1985 | 3.8 | 45 | 2.4 | 49 |
| 1986 | 3.8 | 45 | 2.5 | 49 |

SOURCE: Education Commission of the States, Department of Research and Information, *Clearinghouse Notes*, various years.

See figure 1-14.

## Appendix table 1-26. State minimum competency testing for elementary and secondary school assessment purposes: 1985

| States using minimum competency | Government level setting standards | Grade levels assessed | Test purposes | | | | | First graduating class assessed |
|---|---|---|---|---|---|---|---|---|
| | | | Grade promotion | High school graduation | Early exit | Remediation | Other | |
| Alabama | State | 3,6,9,11 | | X | | X | X | 1985 |
| Arizona | State/Local | 8,12 | ([1]) | X | | | | 1976 |
| Arkansas | State | 3,4,6,8 | | | | X | | |
| California | State/Local | 4-11, 16 yr olds + | | X | X | X | X | |
| Colorado | Local | 9 12 | | Local Opt. | | | | 1979 |
| Connecticut[2] | State | 4,6,8 | | | | X | X | |
| Delaware | State | 1-8,11 | | X | | | X | 1981 |
| Florida | State/Local | 3,5,8,11 | X | X | | | | 1983 |
| Georgia | State | K,1,3,6,8,10 | ([3]) | X | | X | X | 1985 |
| Hawaii[4] | State | 3,9-12 | | X | | X | X | 1983 |
| Idaho | State | 8-12 | | | | X | X | 1982 |
| Illinois | Local | Local Opt. | | | | | Local Opt. | |
| Indiana | Local | 3,6,8,10 | | | | X | X | |
| Kansas[5] | State | 2,4,6,8,10 | | | | | Local Opt. | |
| Kentucky[6] | | K-12 | X | X | | X | | |
| Louisiana[7] | State | 2,3,4,5 | X | | | | | |
| Maryland | State | 7,9 | | X | | X | X | 1982 |
| Massachusetts | Local | Local Opt. | | | | X | | |
| Michigan | State | 4,7,10 | | | | X | Local Opt. | |
| Mississippi | State | 3,5,8,11 | | X | | | X | 1987[8] |
| Missouri | State | 8+ | | | | X | X | |
| Nebraska | Local | 5+ | | | | | X | |
| Nevada | State | 3,6,9,11 | | X | | X | | 1982 |
| New Hampshire[9] | State | 4,8,12 | Local Opt. | Local Opt. | | | Local Opt. | |
| New Jersey | State | 9-12 | | X | | X | X | 1985 |
| New Mexico | State | 10-12 | | | | | X | 1981 |
| New York | State | 3,5,6,8-12 | | X | | X | | 1979 |
| N. Carolina[10] | State | 3,6,8,10 | | X | | | X | 1980 |
| Ohio | Local | Local Opt.[11] | | | | X | Local Opt. | 1990 |
| Oklahoma[12] | None | 3,6,9,12 | | | | | X | |
| Oregon | Local | Local Opt. | X | | | | | 1978 |
| Pennsylvania | State | 3,5,8 | | | | X | | |
| S. Carolina[13] | State | 1,2,3,6,8,11 | X | X | | X | X | 1990 |
| Tennessee | State/Local | 3,6,8,9-12 | X | X | | X | | 1982 |
| Texas | State | 1,3,5,7,9,11,12 | | X | | X | X | 1987 |
| Utah | Local | Local Opt. | | | | X | X | 1986 |
| Vermont | State | 1-8 | | | | | X | 1981 |
| Virginia | State/Local | K-6,10-12 | | X | | | X | |
| Wisconsin | Local | 1-4,5-8,9-10 | | Local Opt. | | X | | |
| Wyoming | Local | Local Opt. | | | | X | | |

[1] 1983 legislation calls for Arizona to develop a minimum course of study and criteria for high school graduation standards and for grade-to-grade promotion criteria. Local school districts are implementing standards.

[2] In Connecticut, a new program of State testing for Grade 4 began in 10/85 and will be expanded to Grades 6 and 8 in 10/86 The testing is the State Criterion-referenced Mastery program. The Grade 9 State proficiency test begun in 1980 will be administered for the final time in 1986.

[3] Effective 8/25, third grade students must demonstrate acceptable performance on criterion-reference tests in mathematics and reading before promotion to the fourth grade. Beginning in 1988/9 school year, students must pass the school readiness test to be eligible for the first grade.

[4] In Hawaii, students have three options: paper/pencil test, performance test, or course. Students must take a paper/pencil test the first time (Grade 9).

[5] The Kansas Minimum Competency Assessment (MCA) was reestablished by 1984 legislative action (SB 473). The MCA will be in effect for 5 school years, 1984/5 through 1988/9.

[6] Kentucky's 1984 legislation required the State Superintendent to recommend a process of using test results for promotion and graduation to the 1986 legislature.

[7] Louisiana added Grade 8 beginning with the 1986/7 school year.

[8] Although the first class assessed graduated in 1987, the first class required to pass for graduation will be the class of 1989.

[9] New Hampshire requires students be tested in elementary, middle, and high school. Some local districts test in grades other than 4, 8, and 12.

(continued)

## Appendix table 1-26. (Continued)

[10] In North Carolina, grades 3, 6, and 8 are given an annual standardized achievement test. Local school districts use the results as a diagnostic tool

[11] Locally based, competency-based education programs are given in the areas of English composition, math, and reading, including testing at least once in grades 1 4 Grades 5-8 and 9-11 shall be implemented later than 1989/90.

[12] Test was given in Oklahoma during the 1978/9 school year. There has been no followup to the program However, a plan for statewide testing was submitted for legislative action in January 1985.

[13] The South Carolina Education Improvement Act of 1984 specifies that the 11th grade test being used to gather base-line data be replaced in the 1985/6 school year with an exit exam in the 10th grade. All students graduating in 1990 and after must pass the exam.

Note: Some states have dates for first high school graduating class to be assessed with no expected use for high school graduation. American Samoa is currently developing a minimum competency testing program.

SOURCE: Educational Commission of the States, Department of Research and Information. State Activity - Minimum Competency Testing," *Clearinghouse Notes*, November 1985

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## Appendix table 1-27. Mean percentage of items taught (opportunity-to-learn) to eighth grade students, by country and subject matter: 1981/2

| Country | Arithmetic | Algebra | Geometry | Statistics | Measurement |
|---|---|---|---|---|---|
| | Percent | | | | |
| Belgium (Flemish) | 76 | 72 | 31 | 39 | 84 |
| Canada (B.C.) | 83 | 84 | 48 | 47 | 77 |
| England/Wales | 78 | 63 | 54 | 69 | 80 |
| Finland | 76 | 70 | 39 | 52 | 70 |
| France | 86 | 87 | 43 | 50 | 92 |
| Hungary | 91 | 91 | 86 | 86 | 97 |
| Israel | 71 | 79 | 46 | 52 | 63 |
| Japan | 85 | 83 | 51 | 76 | 95 |
| Luxembourg | 79 | 52 | 35 | 32 | 82 |
| Netherlands | 82 | 73 | 67 | 32 | 82 |
| New Zealand | 67 | 62 | 59 | 60 | 70 |
| Nigeria | 79 | 72 | 65 | 64 | 71 |
| Canada (Ontario) | 87 | 70 | 49 | 61 | 84 |
| Sweden | 66 | 45 | 35 | 47 | 67 |
| Thailand | 86 | 83 | 57 | 56 | 86 |
| United States | 87 | 69 | 44 | 73 | 72 |

SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987)

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## Appendix table 1-28. Mean percentage of items taught (opportunity-to-learn) to twelfth grade students, by country and subject matter: 1981/2

| Country | Sets and relations | Number systems | Algebra | Geometry | Elementary functions and calculus | Probability and statistics |
|---|---|---|---|---|---|---|
| | Percent | | | | | |
| Belgium (Flemish) | 91 | 80 | 92 | 82 | 88 | 46 |
| Canada (B.C.) | 65 | 75 | 82 | 50 | 32 | 29 |
| England/Wales | 48 | 74 | 86 | 69 | 85 | 87 |
| Finland | 88 | 90 | 92 | 79 | 87 | 87 |
| Hungary | 45 | 55 | 87 | 74 | 67 | 27 |
| Israel | 38 | 56 | 70 | 49 | 79 | 39 |
| Japan | 95 | 80 | 100 | 89 | 92 | 82 |
| New Zealand | 85 | 90 | 93 | 75 | 93 | 86 |
| Canada (Ontario) | 62 | 60 | 83 | 52 | 83 | 33 |
| Sweden | 60 | 87 | 90 | 66 | 85 | 75 |
| Thailand | 81 | 75 | 78 | 63 | 63 | 90 |
| United States | 83 | 83 | 88 | 62 | 54 | 45 |

SOURCE: International Association for the Evaluation of Educational Achievements, *The Underachieving Curriculum Assessing U.S School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987)

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**Appendix table 1-29. Mean percentage score of eighth grade students on the international mathematics achievement test, by country and subject matter: 1981/2**

| Country | Arithmetic | Algebra | Geometry | Statistics | Measurement |
|---|---|---|---|---|---|
| | Percent | | | | |
| Belgium (Flemish) .... | 58 | 53 | 43 | 58 | 58 |
| Belgium (French) ..... | 57 | 49 | 43 | 52 | 57 |
| Canada (B.C.) ....... | 58 | 48 | 42 | 61 | 52 |
| England/Wales ....... | 48 | 40 | 45 | 60 | 49 |
| Finland .............. | 46 | 44 | 43 | 58 | 51 |
| France .............. | 58 | 55 | 38 | 57 | 60 |
| Hong Kong .......... | 55 | 43 | 43 | 56 | 53 |
| Hungary ............. | 57 | 50 | 53 | 60 | 62 |
| Israel ............... | 50 | 44 | 36 | 52 | 46 |
| Japan ............... | 60 | 60 | 58 | 71 | 69 |
| Luxembourg ......... | 45 | 31 | 25 | 37 | 50 |
| Netherlands .......... | 59 | 51 | 52 | 66 | 62 |
| New Zealand ........ | 46 | 39 | 45 | 57 | 45 |
| Nigeria .............. | 41 | 32 | 26 | 37 | 31 |
| Canada (Ontario) ..... | 55 | 42 | 43 | 57 | 51 |
| Scotland ............. | 50 | 43 | 46 | 59 | 48 |
| Swaziland ........... | 32 | 25 | 31 | 36 | 35 |
| Sweden ............. | 41 | 32 | 39 | 56 | 49 |
| Thailand ............. | 43 | 38 | 39 | 45 | 48 |
| United States ........ | 51 | 43 | 38 | 57 | 42 |

SOURCE: International Association for the Evaluation of Educational Achievements. *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective.* University of Illinois (Stipes Publishing Company. January 1987)

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**Appendix table 1-30. Mean percentage score of twelfth grade students on the international mathematics achievement test, by country and subject matter: 1981/2**

| Country | Sets and relations | Number systems | Algebra | Geometry | Elementary functions and calculus | Probability and statistics |
|---|---|---|---|---|---|---|
| | Percent | | | | | |
| Belgium (Flemish) ................ | 72 | 48 | 61 | 42 | 46 | 43 |
| Belgium (French) ................ | 66 | 44 | 55 | 38 | 43 | 42 |
| Canada (B. C) .................... | 48 | 43 | 47 | 30 | 21 | 38 |
| England/Wales .................... | 61 | 59 | 66 | 51 | 58 | 64 |
| Finland .......................... | 77 | 57 | 69 | 48 | 55 | 58 |
| Hong Kong ....................... | 80 | 78 | 78 | 65 | 71 | 73 |
| Hungary .......................... | 35 | 28 | 45 | 30 | 26 | 29 |
| Israel ............................ | 51 | 46 | 60 | 35 | 45 | 38 |
| Japan ........................... | 79 | 68 | 78 | 60 | 66 | 70 |
| New Zealand .................... | 72 | 51 | 57 | 43 | 48 | 58 |
| Canada (Ontario) ................ | 69 | 47 | 57 | 42 | 46 | 46 |
| Scotland ......................... | 50 | 39 | 48 | 42 | 32 | 46 |
| Sweden .......................... | 59 | 62 | 60 | 49 | 51 | 64 |
| Thailand ......................... | 52 | 33 | 38 | 28 | 26 | 34 |
| United States ..................... | 56 | 40 | 43 | 31 | 29 | 40 |

SOURCES: International Association for the Evaluation of Educational Achievement. *The Underachieving Curriculum Assessing U.S. School Mathematics from an International Perspective.* University of Illinois (Stipes Publishing Company. January 1987)

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## Appendix table 1-31. Average percent new content in three mathematics text series — comparison of the first 200 pages and the remainder of the book

| | Grade level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | Percent | | | | | | | | |
| First 200 pages .... ............. | 70 | 28 | 52 | 31 | 37 | 26 | 27 | 19 | 77 |
| Remainder of book ............... | 80 | 63 | 79 | 61 | 61 | 53 | 44 | 40 | 95 |

SOURCE: Glanders, Jim, "How Much of the Content in Mathematics Textbooks is New?", University of Chicago (Unpublished report, November 13, 1986)

See figure 1-17

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## Appendix table 1-32. Attitudes of eighth and twelfth grade mathematics students towards mathematics in their personal lives: 1981/2

| | 8th Grade | 12th Grade |
|---|---|---|
| | — Percent giving a high rating — | |
| I usually understand what we are talking about in class ................................ | 71 | 75 |
| I really want to do well in mathematics .......... ... | 87 | 91 |
| I feel good when I solve a mathematics problem by myself .................................... | 78 | 91 |
| My parents really do want me to do well in mathematics[1] ............................... | 86 | 89 |
| It does not scare me to have to take mathematics .... | 7[illegible] | 81 |
| Mathematics is easier for me than for most persons[1] ................................ | 56 | 76 |
| If I had a choice, I would learn more mathematics[1] ............................ | 66 | 76 |
| Mathematics helps me think logically ................ | 64 | 85 |
| There is usually a rule to follow in mathematics .................................. | 82 | 67 |

[1] Reworded to capture the positive intent of the question

SOURCE: Travers, K. J., *Second Study of Mathematics, Detailed National Report — United States*, December, 1986, pp. 382-384

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## Appendix table 1-33. Attitudes of eighth grade U.S. students towards mathematics: 1981/2

| | Percent giving a high rating to: | | |
|---|---|---|---|
| | Importance | Ease | Likes |
| Memorizing | 84 | 36 | 22 |
| Measures | 83 | 52 | 43 |
| Checking | 79 | 72 | 25 |
| Equations | 78 | 53 | 44 |
| Decimals | 76 | 56 | 44 |
| Estimating | 68 | 68 | 49 |
| Charts and graphs | 67 | 74 | 57 |
| Ratios and proportions | 67 | 45 | 35 |
| Word problems | 66 | 39 | 28 |
| Tables | 61 | 49 | 37 |
| Geometric figures | 60 | 45 | 38 |
| Calculators | 54 | 86 | 75 |
| Inequalities | 50 | 35 | 25 |
| Sets | 47 | 57 | 38 |
| Drawing figures | 46 | 55 | 42 |
| All subtopics | 66 | 55 | 40 |

Note: Attitudes were obtained at the end of the school year, after exposure to these topics.

SOURCE: Travers, K. J, *Second Study in Mathematics, Detailed National Report — United States*, December, 1986, pp. 367-369

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## Appendix table 1-34. Attitudes of twelfth grade U.S. students towards mathematics: 1981/2

| | Percent giving a high rating to: | | |
|---|---|---|---|
| | Importance | Ease | Likes |
| Equations | 94 | 71 | 71 |
| Checking | 90 | 78 | 29 |
| Memorizing | 85 | 46 | 18 |
| Calculators | 80 | 35 | 85 |
| Word problems | 78 | 26 | 29 |
| Function graphs | 69 | 64 | 37 |
| Probability | 66 | 34 | 37 |
| Charts and graphs | 62 | 80 | 42 |
| Complex numbers | 62 | 52 | 37 |
| Derivatives | 56 | 37 | 34 |
| Limits | 55 | 42 | 30 |
| Sequences and series | 53 | 43 | 33 |
| Proofs | 52 | 20 | 18 |
| Vectors | 48 | 41 | 30 |
| Integrals | 46 | 26 | 25 |
| All subtopics | 66 | 50 | 37 |

Note: Attitudes were obtained at the end of the school year, after exposure to these topics.

SOURCE: Travers, K. J., *Second Study in Mathematics, Detailed National Report — United States*, December, 1986, pp. 371-373

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## Appendix table 2-1. U.S. population and college enrollment of 18-21 year olds, by selected race and gender, 1970-85

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —Thousands— | | | | | | | | |
| Total male population | 6,000 | 6,389 | 6,882 | 7,080 | 7,350 | 7,584 | 7.729 | 7,823 | 7.886 | 7,941 | 7,922 | 8,052 | 7,917 | 7,796 | 7,554 | 7,260 |
| Total male enrollment | 2,429 | 2,534 | 2,536 | 2,423 | 2,468 | 2.682 | 2,600 | 2,676 | 2,593 | 2,533 | 2,615 | 2,689 | 2,722 | 2,650 | 2 710 | 2,662 |
| Percent | 40.5 | 39.7 | 36.8 | 34.2 | 33.6 | 35.4 | 33.6 | 34.2 | 32.9 | 31.9 | 33.0 | 33.4 | 34.4 | 34.0 | 35.9 | 36.7 |
| Total female population | 7,076 | 7,250 | 7,535 | 7,683 | 7,943 | 8,109 | 8,230 | 8.318 | 8.359 | 8,373 | 8,350 | 8,428 | 8,276 | 8,062 | 7,833 | 7,623 |
| Total female enrollment | 2,022 | 2,187 | 2,260 | 2,178 | 2,321 | 2,575 | 2,735 | 2,668 | 2,603 | 2,664 | 2,743 | 2,899 | 2,896 | 2,785 | 2,754 | 2.862 |
| Percent | 28.6 | 30.2 | 30.0 | 28.3 | 29.2 | 31.8 | 33.2 | 32.1 | 31.1 | 31.8 | 32.9 | 34.4 | 35.0 | 34.5 | 35.2 | 37.5 |
| White male population | 5,194 | 5,531 | 5,973 | 6,129 | 6,373 | 6,545 | 6.651 | 6,730 | 6,783 | 6,827 | 6,793 | 6,820 | 6,626 | 6,501 | 6,289 | 6,069 |
| White male enrollment | 2,246 | 2,292 | 2,304 | 2,194 | 2,210 | 2,417 | 2,317 | 2,396 | 2,275 | 2,250 | 2,346 | 2.363 | 2,377 | 2,346 | 2,367 | 2,313 |
| Percent | 43.2 | 41.4 | 38.6 | 35.8 | 34.7 | 36.9 | 34.8 | 35.6 | 33.5 | 33.0 | 34.5 | 34.6 | 35.9 | 36.1 | 37.6 | 38.1 |
| White female population | 6,099 | 6,238 | 6,481 | 6,573 | 6,784 | 6,903 | 6,991 | 7,051 | 7,073 | 7,072 | 7,033 | 7,051 | 6,895 | 6,689 | 6,461 | 6,280 |
| White female enrollment | 1,799 | 1,951 | 2,024 | 1,952 | 2,039 | 2,238 | 2,368 | 2,282 | 2,251 | 2,327 | 2,363 | 2,514 | 2,519 | 2,412 | 2,380 | 2,483 |
| Percent | 29.5 | 31.3 | 31.2 | 29.7 | 30.1 | 32.4 | 33.9 | 32.4 | 31.8 | 32.9 | 33.6 | 35.7 | 36.5 | 36.1 | 36.8 | 39.5 |
| Black male population | 746 | 779 | 825 | 854 | 865 | 941 | 957 | 946 | 951 | 956 | 967 | 1,032 | 1,058 | 1,059 | 1,040 | 1,017 |
| Black male enrollment | 154 | 200 | 193 | 189 | 202 | 218 | 234 | 205 | 220 | 220 | 199 | 225 | 216 | 205 | 241 | 261 |
| Percent | 20.6 | 25.7 | 23.4 | 22.1 | 23.4 | 23.2 | 24.5 | 21.7 | 23.1 | 23.0 | 20.6 | 21.8 | 20.4 | 19.4 | 23.2 | 25.7 |
| Black female population | 896 | 932 | 980 | 998 | 1,031 | 1,085 | 1,110 | 1,150 | 1,132 | 1,137 | 1,148 | 1,193 | 1,194 | 1,177 | 1,167 | 1,132 |
| Black female enrollment | 189 | 202 | 204 | 168 | 222 | 280 | 320 | 326 | 288 | 283 | 309 | 312 | 300 | 295 | 298 | 272 |
| Percent | 21.1 | 21.7 | 20.8 | 16.8 | 21.5 | 25.8 | 28.8 | 28.8 | 25.4 | 24.9 | 26.9 | 26.2 | 25.1 | 25.1 | 25.5 | 24.0 |
| Hispanic male population | NA | NA | 372 | 355 | 428 | 416 | 458 | 462 | 439 | 486 | 589 | 611 | 559 | 577 | 508 | 551 |
| Hispanic male enrollment | NA | NA | 83 | 76 | 99 | 105 | 108 | 99 | 83 | 110 | 120 | 125 | 99 | 102 | 105 | 97 |
| Percent | NA | NA | 22.3 | 21.4 | 23.1 | 25.2 | 23.6 | 21.4 | 18.9 | 22.6 | 20.4 | 20.5 | 17.7 | 17.7 | 20.7 | 17.6 |
| Hispanic female population | NA | NA | 419 | 382 | 466 | 484 | 507 | 519 | 521 | 525 | 578 | 642 | 561 | 610 | 579 | 594 |
| Hispanic female enrollment | NA | NA | 68 | 77 | 107 | 114 | 119 | 120 | 94 | 110 | 110 | 127 | 148 | 157 | 164 | 157 |
| Percent | NA | NA | 16.2 | 20.2 | 23.0 | 23.6 | 23.5 | 23.1 | 18.0 | 21.0 | 19.0 | 19.8 | 26.4 | 25.7 | 28.3 | 26.4 |

Note: NA = Not Available.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Population Report* (Series P-20) various issues

See figure O-18 in Overview

Appendix table 2-2. S/E graduate enrollments of U.S. citizens in all institutions, by field, race, and enrollment status: 1980-86

| | Full-time | | | | | | Part-time | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1982 | 1983 | 1984 | 1985 | 1986 | 1980 | 1982 | 1983 | 1984 | 1985 | 1986 |
| Total science and engineering | 198,429 | 197,374 | 200,906 | 202,699 | 201,153 | 203,559 | NA | 133,190 | 138,088 | 146,775 | 152,173 | 154,120 |
| White | 149,481 | 159,171 | 168,044 | 167,013 | 163,139 | 165,975 | 79,174 | 102,410 | 108,791 | 111,203 | 114,648 | 116,179 |
| Black | 6,607 | 7,225 | 7,469 | 7,632 | 7,272 | 7,275 | 5,020 | 6,100 | 6,999 | 7,238 | 7,295 | 7,119 |
| Hispanic | 4,922 | 5,496 | 6,486 | 6,873 | 6,723 | 7,066 | 2,490 | [illegible] | 4,683 | 5,189 | 4,692 | 4,485 |
| Asian | 5,394 | 5,657 | 6,457 | 7,482 | 8,314 | 9,291 | 2,830 | 3,678 | 4,200 | 4,845 | 5,850 | 5,893 |
| Other U.S. citizens | 32,025 | 19,825 | 12,450 | 13,699 | 15,705 | 13,952 | NA | 17,172 | 13,415 | 18,300 | 19,688 | 20,444 |
| Foreign | 50,730 | 57,923 | 62,784 | 64,622 | 69,201 | [illegible] | NA | 10,495 | 11,577 | 12,304 | 12,096 | 12,747 |
| Total sciences | 173,321 | 168,558 | 168,759 | 169,733 | 168,086 | 169. | NA | 102,621 | 104,915 | 111,445 | 114,628 | 115,694 |
| White | 130,878 | 137,494 | 142,848 | 141,266 | 137,755 | 139,092 | 60,803 | 80,711 | 84,005 | 84,415 | 87,607 | 88,484 |
| Black | 6,135 | 6,706 | 6,803 | 6,920 | 6,547 | 6,490 | 4,562 | 5,475 | 6,246 | 6,407 | 6,511 | 6,344 |
| Hispanic | 4,350 | 4,895 | 5,701 | 6,095 | 5,941 | 6,190 | 1,978 | 3,330 | 3,973 | 4,310 | 3,879 | 3,678 |
| Asian | 3,888 | 4,238 | 4,698 | 5,268 | 5,671 | 6,392 | 1,626 | 2,350 | 2,497 | 2,842 | 3,355 | 3,354 |
| Other U.S. citizens | 28,070 | 15,225 | 8,709 | 10,184 | 12,172 | 10,976 | NA | 10,755 | 8,194 | 13,471 | 13,276 | 13,834 |
| Foreign | 32,731 | 36,500 | 39,738 | 41,006 | 44,779 | 48,363 | NA | 6,709 | 6,788 | 7,395 | 7,188 | 7,611 |
| Physical sciences | 17,174 | 17,555 | 17,981 | 18,271 | 18,150 | 18,369 | NA | 3,699 | 3,832 | 4,150 | 4,106 | 4,444 |
| White | 13,919 | 14,742 | 15,478 | 15,423 | 15,186 | 15,338 | 2,404 | 2,947 | 3,185 | 3,415 | 3,293 | 3,463 |
| Black | 323 | 418 | 412 | 440 | 385 | 400 | 96 | 135 | 163 | 173 | 163 | 165 |
| Hispanic | 305 | 387 | 449 | 461 | 526 | 556 | 65 | 109 | 114 | 80 | 78 | 98 |
| Asian | 513 | 532 | 590 | 759 | 789 | 863 | 113 | 165 | 159 | 183 | 183 | 201 |
| Other U.S. citizens | 2,114 | 1,476 | 1,052 | 1,188 | 1,264 | 1,212 | NA | 343 | 211 | 299 | 389 | 517 |
| Foreign | 5,744 | 6,485 | 7,232 | 7,603 | 8,472 | 9,329 | NA | 460 | 430 | 464 | 467 | 569 |
| Environmental sciences | 9,570 | 9,789 | 10,391 | 10,125 | 9,693 | 9,452 | NA | 3,501 | 3,343 | 3,870 | 4,139 | 3,868 |
| White | 7,523 | 8,388 | 9,348 | 8,726 | 8,445 | 8,406 | 2,230 | 3,005 | 3,023 | 3,416 | 3,458 | 3,257 |
| Black | 66 | 76 | 83 | 86 | 85 | 66 | 38 | 27 | 29 | 26 | 42 | 36 |
| Hispanic | 115 | 132 | 146 | 198 | 198 | 206 | 34 | 59 | 81 | 74 | 74 | 65 |
| Asian | 143 | 136 | 158 | 149 | 155 | 143 | 27 | 72 | 85 | 45 | 38 | 34 |
| Other U.S. citizens | 1,723 | 1,057 | 656 | 966 | 810 | 631 | NA | 338 | 125 | 309 | 527 | [illegible] |
| Foreign | 1,399 | 1,647 | 1,698 | 1,590 | 1,697 | 1,813 | NA | 237 | 177 | 218 | 212 | [illegible] |
| Mathematical sciences | 6,648 | 6,935 | 6,726 | 6,840 | 7,079 | 7,263 | NA | 5,733 | 5,756 | 5,708 | 5,597 | [illegible] |
| White | 5,042 | 5,571 | 5,589 | 5,592 | 5,675 | 5,846 | 3,034 | 4,587 | 4,742 | 4,424 | 4,196 | [illegible] |
| Black | 141 | 174 | 164 | 185 | 199 | 242 | 159 | 183 | 240 | 215 | 224 | 206 |
| Hispanic | 140 | 174 | 205 | 185 | 163 | 182 | 50 | 116 | 127 | 113 | 104 | 123 |
| Asian | 205 | 298 | 337 | 324 | 435 | 469 | 119 | 194 | 227 | 310 | 257 | 258 |
| Other U.S. citizens | 1,120 | 718 | 431 | 554 | 607 | 524 | NA | 653 | 420 | 646 | 816 | 992 |
| Foreign | 3,254 | 3,888 | 4,245 | 4,592 | 4,884 | 5,193 | NA | 643 | 716 | 691 | 546 | 715 |
| Computer sciences | 4,521 | 5,981 | 6,724 | 6,905 | 8,463 | 9,100 | NA | 9,458 | 11,344 | 12,230 | 13,684 | 13,772 |
| White | 2,793 | 4,339 | 5,053 | 5,209 | 5,815 | 6,482 | 3,758 | 7,235 | 8,429 | 9,430 | 9,247 | 9,308 |
| Black | 67 | 198 | 207 | 193 | 188 | 276 | 126 | 330 | 357 | 335 | 390 | 383 |
| Hispanic | 42 | 105 | 105 | 111 | 128 | 170 | 58 | 144 | 177 | 149 | 283 | 255 |
| Asian | 200 | 365 | 558 | 534 | 741 | 895 | 369 | 525 | 541 | 616 | 1,059 | 1,144 |
| Other U.S. citizens | 1,419 | 974 | 801 | 856 | 1,591 | 1,277 | NA | 1,224 | 1,840 | 2,700 | 2,705 | 2,682 |
| Foreign | 2,066 | 3,190 | 3,963 | 4,423 | 5,465 | 5,971 | NA | 1,183 | 1,585 | 1,806 | 1,910 | 1,883 |
| Life sciences | 63,543 | 60,522 | 59,690 | 59,580 | 58,790 | 58,344 | NA | 31,106 | 32,159 | 33,638 | 34,927 | 35,755 |
| White | 50,716 | 51,880 | 52,517 | 52,171 | 50,217 | 50,196 | 20,476 | 26,344 | 27,441 | 28,154 | 28,567 | 29,224 |
| Black | 1,633 | 1,697 | 1,730 | 1,735 | 1,829 | 1,731 | 1,078 | 1,244 | 1,526 | 1,679 | 1,744 | 1,620 |
| Hispanic | 1,451 | 1,338 | 1,776 | 1,816 | 2,091 | 2,056 | 521 | 603 | 811 | 810 | 949 | 856 |
| Asian | 1,644 | 1,622 | 1,691 | 1,871 | 2,021 | 2,250 | 457 | 603 | 679 | 729 | 817 | 824 |
| Other U.S. citizens | 8,099 | 3,985 | 1,976 | 1,987 | 2,632 | 2,111 | NA | 2,312 | 1,702 | 2,266 | 2,850 | 3,231 |
| Foreign | 8,866 | 9,732 | 10,421 | 10,762 | 11,387 | 12,585 | NA | 1,529 | 1,432 | 1,569 | 1,549 | 1,643 |
| Psychology | 25,482 | 24,739 | 25,657 | 25,974 | 25,429 | 25,871 | NA | 13,965 | 14,015 | 16,868 | 17,032 | 16,468 |
| White | 17,612 | 19,198 | 21,369 | 20,769 | 20,710 | 21,133 | 7,124 | 11,123 | 11,333 | 12,460 | 13,354 | 12,954 |
| Black | 1,017 | 1,021 | 1,145 | 1,172 | 1,116 | 1,142 | 401 | 622 | 771 | 1,026 | 959 | 905 |
| Hispanic | 971 | 1,032 | 1,146 | 1,391 | 1,038 | 1,193 | 327 | 439 | 684 | 1,204 | 712 | 676 |
| Asian | 302 | 319 | 368 | 463 | 423 | 510 | 70 | 122 | 164 | 236 | 260 | 240 |
| Other U.S. citizens | 5,580 | 3,169 | 1,629 | 2,179 | 2,142 | 1,893 | NA | 1,659 | 1,063 | 1,942 | 1,747 | 1,693 |
| Foreign | 1,210 | 1,079 | 1,092 | 1,089 | 1,228 | 1,215 | NA | 315 | 340 | 374 | 372 | 350 |
| Social sciences | 46,383 | 43,037 | 41,590 | 42,039 | 40,482 | 40,742 | NA | 35,159 | 34,466 | 34,982 | 35,144 | 36,178 |
| White | 33,273 | 33,376 | 33,494 | 33,377 | 31,707 | 31,691 | 21,777 | 25,470 | 25,852 | 25,117 | 25,494 | 26,649 |
| Black | 2,888 | 3,122 | 3,062 | 3,107 | 2,746 | 2,634 | 2,664 | 2,934 | 3,160 | 2,951 | 2,989 | 3,030 |
| Hispanic | 1,326 | 1,727 | 1,874 | 1,932 | 1,797 | 1,828 | 923 | 1,860 | 1,979 | 1,880 | 1,680 | 1,605 |
| Asian | 881 | 966 | 996 | 1,167 | 1,108 | 1,263 | 471 | 669 | 642 | 723 | 740 | 652 |
| Other U.S. citizens | 8,015 | 3,846 | 2,164 | 2,456 | 3,124 | 3,326 | NA | 4,226 | 2,833 | 4,311 | 4,241 | 4,242 |
| Foreign | 10,192 | 10,479 | 11,087 | 10,948 | 11,647 | 12,257 | NA | 2,342 | 2,108 | 2,273 | 2,131 | 2,243 |
| Total engineering | 25,108 | 28,816 | 32,147 | 32,965 | 33,066 | 34,418 | NA | 30,569 | 33,173 | 35,330 | 37,545 | 38,426 |
| White | 18,603 | 21,677 | 25,196 | 25,747 | 25,384 | 26,884 | 18,371 | 21,699 | 24,786 | 25,788 | 27,041 | 27,695 |
| Black | 472 | 519 | 666 | 712 | 724 | 784 | 458 | 625 | 753 | 832 | 784 | 775 |
| Hispanic | 572 | 601 | 785 | 778 | 782 | 877 | 512 | 500 | 710 | 879 | 813 | 807 |
| Asian | 1,506 | 1,419 | 1,759 | 2,214 | 2,643 | 2,899 | 1,204 | 1,328 | 1,703 | 2,003 | 2,496 | 2,540 |
| Other U.S. citizens | 3,955 | 4,600 | 3,741 | 3,514 | 3,533 | 2,974 | NA | 6,417 | 5,221 | 5,828 | 6,411 | 6,609 |
| Foreign | 17,999 | 21,423 | 23,046 | 23,616 | 24,421 | 27,314 | NA | 3,786 | 4,709 | 4,909 | 4,908 | 5,136 |

Note NA - Not Available

SOURCE: National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support, Fall 1986* (forthcoming)

See figure 2-2

## Appendix table 2-3. S/E enrollment of U.S. citizens in doctorate-granting institutions by field, race, and enrollment status: 1980-86

| Field and race | Full-time | | | | | | | Part-time | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
| Total science and engineering | 181,864 | 181,593 | 181,637 | 183,642 | 185,283 | 184,753 | 187,171 | NA | NA | 101,311 | 104,834 | 106,299 | 111,067 | 113,710 |
| White | 140,799 | 133,217 | 148,143 | 155,420 | 155,634 | 153,257 | 156,317 | 63,728 | 62,124 | 79,692 | 84,039 | 83,836 | 87,502 | 90,401 |
| Black | 5,595 | 5,402 | 5,992 | 5,996 | 5,938 | 5,956 | 5,973 | 3,747 | 3,546 | 4,315 | 4,844 | 4,641 | 4,533 | 4,558 |
| Hispanic | 4,535 | 4,117 | 5,024 | 5,746 | 5,853 | 6,066 | 6,431 | 1,910 | 2,183 | 2,981 | 3,464 | 3,346 | 3,251 | 3,367 |
| Asian | 5,073 | 4,590 | 5,224 | 5,843 | 6,658 | 7,509 | 8,500 | 2,246 | 2,269 | 2,808 | 2,989 | 3,057 | 3,967 | 4,120 |
| Total sciences | 157,428 | 155,977 | 153,762 | 152,532 | 153,321 | 152,550 | 153,873 | NA | NA | 75,058 | 76,138 | 76,968 | 79,780 | 81,030 |
| White | 122,458 | 115,178 | 126,991 | 130,896 | 130,465 | 128,308 | 130,059 | 46,705 | 44,859 | 60,804 | 62,504 | 62,237 | 64,689 | 66,014 |
| Black | 5,159 | 5,008 | 5,519 | 5,386 | 5,279 | 5,295 | 5,246 | 3,349 | 3,159 | 3,804 | 4,245 | 3,979 | 3,944 | 3,957 |
| Hispanic | 3,973 | 3,638 | 4,454 | 5,002 | 5,124 | 5,339 | 5,579 | 1,482 | 1,793 | 2,557 | 2,877 | 2,661 | 2,624 | 2,652 |
| Asian | 3,589 | 3,522 | 3,902 | 4,206 | 4,582 | 5,010 | 5,751 | 1,229 | 1,325 | 1,721 | 1,750 | 1,787 | 2,151 | 2,165 |
| Physical sciences | 16,668 | 16,523 | 17,038 | 17,451 | 17,720 | 17,700 | 17,922 | NA | NA | 2,822 | 2,907 | 2,900 | 2,987 | 3,100 |
| White | 13,638 | 13,260 | 14,415 | 15,138 | 15,119 | 14,926 | 15,097 | 1,924 | 1,904 | 2,319 | 2,486 | 2,514 | 2,440 | 2,617 |
| Black | 262 | 274 | 339 | 330 | 363 | 301 | 314 | 70 | 71 | 95 | 97 | 93 | 87 | 86 |
| Hispanic | 288 | 315 | 375 | 434 | 444 | 514 | 531 | 49 | 40 | 86 | 105 | 63 | 50 | 56 |
| Asian | 495 | 452 | 502 | 538 | 683 | 742 | 835 | 81 | 113 | 126 | 103 | 104 | 95 | 88 |
| Environmental sciences | 8,930 | 9,026 | 9,269 | 9,805 | 9,730 | 9,277 | 9,111 | NA | | 2,674 | 2,652 | 2,855 | 3,154 | 2,969 |
| White | 7,170 | 6,849 | 7,999 | 8,881 | 8,403 | 8,108 | 8,139 | 1,787 | 1,661 | 2,383 | 2,446 | 2,580 | 2,818 | 2,723 |
| Black | 54 | 59 | 59 | 77 | 79 | 82 | 62 | 18 | 20 | 16 | 22 | 22 | 29 | 28 |
| Hispanic | 111 | 125 | 112 | 136 | 184 | 160 | 180 | 22 | 21 | 44 | 65 | 59 | 33 | 37 |
| Asian | 135 | 100 | 130 | 145 | 133 | 147 | 137 | 18 | 15 | 48 | 63 | 24 | 20 | 9 |
| Mathematical sciences | 6,213 | 6,159 | 6,453 | 6,232 | 6,266 | 6,516 | 6,805 | NA | NA | 4,078 | 4,025 | 3,910 | 3,661 | 3,370 |
| White | 4,852 | 4,599 | 5,227 | 5,223 | 5,226 | 5,325 | 5,587 | 2,490 | 2,564 | 3,286 | 3,361 | 3,193 | 3,012 | 2,611 |
| Black | 106 | 119 | 146 | 126 | 134 | 162 | 191 | 114 | 120 | 122 | 147 | 121 | 105 | 110 |
| Hispanic | 125 | 157 | 163 | 201 | 163 | 161 | 168 | 31 | 46 | 81 | 94 | 82 | 70 | 80 |
| Asian | 197 | 231 | 278 | 285 | 246 | 352 | 416 | 95 | 89 | 126 | 141 | 175 | 145 | 155 |
| Computer sciences | 4,030 | 4,260 | 5,137 | 5,755 | 6,109 | 7,529 | 8,065 | NA | NA | 6,817 | 7,787 | 8,721 | 9,863 | 10,377 |
| White | 2,513 | 3,161 | 3,850 | 4,415 | 4,736 | 5,557 | 6,182 | 3,090 | 3,250 | 5,375 | 5,781 | 6,153 | 7,180 | 7,459 |
| Black | 38 | 70 | 116 | 117 | 128 | 154 | 228 | 79 | 119 | 233 | 253 | 249 | 303 | 282 |
| Hispanic | 30 | 37 | 86 | 83 | 97 | 106 | 152 | 38 | 36 | 90 | 111 | 111 | 229 | 211 |
| Asian | 142 | 199 | 279 | 442 | 453 | 597 | 727 | 253 | 306 | 366 | 363 | 437 | 778 | 818 |
| Life sciences | 59,226 | 58,183 | 56,343 | 55,139 | 55,890 | 55,112 | 55,054 | NA | NA | 23,800 | 24,873 | 25,300 | 25,990 | 27,380 |
| White | 48,155 | 45,304 | 48,644 | 48,869 | 49,474 | 47,680 | 47,801 | 15,902 | 15,540 | 20,723 | 21,657 | 21,981 | 22,048 | 23,362 |
| Black | 1,346 | 1,203 | 1,399 | 1,367 | 1,377 | 1,457 | 1,441 | 765 | 680 | 861 | 1,045 | 1,115 | 1,119 | 1,112 |
| Hispanic | 1,357 | 855 | 1,236 | 1,604 | 1,657 | 1,908 | 1,916 | 368 | 307 | 433 | 576 | 529 | 576 | 645 |
| Asian | 1,545 | 1,321 | 1,559 | 1,603 | 1,756 | 1,831 | 2,127 | 381 | 312 | 475 | 522 | 474 | 510 | 529 |
| Psychology | 20,526 | 20,712 | 20,216 | 20,403 | 20,653 | 20,476 | 20,993 | NA | NA | 7,759 | 7,488 | 8,135 | 8,784 | 8,491 |
| White | 14,764 | 13,062 | 15,574 | 17,311 | 17,255 | 17,242 | 17,659 | 4,233 | 3,991 | 6,361 | 6,146 | 6,337 | 6,897 | 6,762 |
| Black | 830 | 788 | 802 | 862 | 863 | 825 | 835 | 194 | 263 | 329 | 406 | 449 | 373 | 361 |
| Hispanic | 846 | 871 | 936 | 897 | 938 | 917 | 1,037 | 199 | 187 | 304 | 370 | 421 | 462 | 423 |
| Asian | 247 | 291 | 274 | 289 | 321 | 341 | 389 | 41 | 43 | 78 | 84 | 89 | 99 | 99 |
| Social sciences | 41,835 | 41,114 | 39,306 | 37,747 | 36,953 | 35,940 | 35,923 | NA | NA | 27,108 | 26,406 | 25,147 | 25,341 | 25,343 |
| White | 31,366 | 28,943 | 31,282 | 31,059 | 30,252 | 29,470 | 29,594 | 17,279 | 15,949 | 20,357 | 20,627 | 19,479 | 20,294 | 20,480 |
| Black | 2,523 | 2,495 | 2,658 | 2,507 | 2,335 | 2,314 | 2,175 | 2,109 | 1,886 | 2,148 | 2,275 | 1,930 | 1,928 | 1,978 |
| Hispanic | 1,216 | 1,278 | 1,546 | 1,647 | 1,636 | 1,573 | 1,595 | 775 | 1,156 | 1,519 | 1,556 | 1,396 | 1,204 | 1,200 |
| Asian | 828 | 928 | 880 | 904 | 990 | 1,000 | 1,120 | 360 | 447 | 502 | 474 | 484 | 504 | 467 |
| Total engineering | 24,436 | 25,616 | 27,875 | 31,110 | 31,962 | 32,203 | 33,298 | NA | NA | 26,253 | 28,696 | 29,331 | 31,287 | 32,680 |
| White | 18,341 | 18,039 | 21,152 | 24,524 | 25,169 | 24,949 | 26,258 | 17,023 | 17,265 | 18,888 | 21,535 | 21,599 | 22,813 | 24,387 |
| Black | 436 | 394 | 473 | 610 | 659 | 661 | 727 | 398 | 387 | 511 | 599 | 662 | 589 | 601 |
| Hispanic | 562 | 479 | 570 | 744 | 729 | 727 | 852 | 428 | 390 | 424 | 587 | 685 | 627 | 715 |
| Asian | 1,484 | 1,068 | 1,322 | 1,637 | 2,076 | 2,499 | 2,749 | 1,017 | 944 | 1,087 | 1,239 | 1,270 | 1,816 | 1,955 |

SOURCE. National Science Foundation, *Academic Science/Engineering. Graduate Enrollment Fall 1986* (forthcoming), unpublished data

**Appendix table 2-4. Full-time S/E graduate students in doctorate-granting institutions, by field and citizenship: 1980-86**

| Field and citizenship | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| Total science and engineering | 230,535 | 234,194 | 236,939 | 243,540 | 246,718 | 251,147 | 259,980 |
| Foreign | 48,671 | 52,601 | 55,302 | 59,898 | 61,435 | 66,394 | 72,809 |
| Total sciences | 188,596 | 189,377 | 188,252 | 190,024 | 191,961 | 195,207 | 200,055 |
| Foreign | 31,168 | 33,400 | 34,490 | 37,492 | 38,640 | 42,657 | 46,182 |
| Physical sciences | 22,254 | 22,600 | 23,330 | 24,492 | 25,149 | 25,967 | 27,074 |
| Foreign | 5,586 | 6,077 | 6,292 | 7,041 | 7,429 | 8,267 | 9,152 |
| Environmental sciences | 10,265 | 10,491 | 10,873 | 11,466 | 11,283 | 10,918 | 10,909 |
| Foreign | 1,335 | 1,465 | 1,604 | 1,661 | 1,553 | 1,641 | 1,798 |
| Mathematical sciences | 9,368 | 9,680 | 10,174 | 10,312 | 10,613 | 11,168 | 11,767 |
| Foreign | 3,155 | 3,521 | 3,721 | 4,080 | 4,347 | 4,652 | 4,962 |
| Computer sciences | 5,900 | 6,465 | 7,908 | 9,267 | 10,108 | 12,433 | 13,504 |
| Foreign | 1,870 | 2,205 | 2,771 | 3,512 | 3,999 | 4,904 | 5,439 |
| Life sciences | 67,711 | 67,195 | 65,653 | 65,098 | 66,044 | 66,112 | 67,205 |
| Foreign | 8,485 | 9,012 | 9,310 | 9,959 | 10,154 | 11,000 | 12,151 |
| Psychology | 21,580 | 21,544 | 21,103 | 21,309 | 21,578 | 21,524 | 22,007 |
| Foreign | 1,054 | 832 | 887 | 906 | 925 | 1,048 | 1,014 |
| Social sciences | 51,518 | 51,402 | 49,211 | 48,080 | 47,186 | 47,085 | 47,589 |
| Foreign | 9,683 | 10,288 | 9,905 | 10,333 | 10,233 | 11,145 | 11,666 |
| Total engineering | 41,939 | 44,817 | 48,687 | 53,516 | 54,757 | 55,940 | 59,925 |
| Foreign | 17,503 | 19,201 | 20,812 | 22,406 | 22,795 | 23,737 | 26,627 |

SOURCE: National Science Foundation, *Academic Science/Engineering. Graduate Enrollment and Support. Fall 1986* (forthcoming)

See figure O-20 in Overview

Science & Engineering Indicators—1987

## Appendix table 2-5. S/E graduate students in doctorate and master's granting institutions, by field and enrollment status: 1980-86

| Field and enrollment | 1980 FT | 1980 PT | 1981 FT | 1981 PT | 1982 FT | 1982 PT | 1983 FT | 1983 PT | 1984 FT | 1984 PT | 1985 FT | 1985 PT | 1986 FT | 1986 PT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total science and engineering ... | 249,159 | 133,941 | 252,997 | 138,643 | 255,297 | 143,685 | 263,690 | 149,665 | 267,320 | 159,079 | 270,353 | 164,269 | 279,235 | 166,867 |
| Doctorate-granting ... ..... | 230,535 | 103,134 | 234,194 | 105,774 | 236,939 | 109,857 | 243,540 | 104,523 | 246,718 | 116,350 | 251,147 | 120,875 | 259,980 | 124,223 |
| Master's granting ........... | 18,624 | 30,807 | 18,803 | 32,869 | 18,358 | 33,828 | 20,150 | 35,142 | 20,602 | 42,729 | 19,206 | 43,394 | 19,255 | 42,644 |
| Total sciences .............. ... | 206,052 | 101,964 | 206,740 | 104,421 | 205,058 | 109,330 | 208,497 | 11,703 | 210,739 | 118,840 | 212,865 | 121,816 | 217,503 | 123,305 |
| Doctorate-granting ...... .. . | 188,596 | 74,930 | 189,377 | 76,218 | 188,252 | 80,366 | 190,024 | 81,628 | 191,961 | 82,835 | 195,207 | 85,431 | 200,055 | 87,116 |
| Master's granting ........ . . | 17,456 | 27,034 | 17,363 | 28,203 | 16,806 | 28,964 | 18,473 | 30,075 | 18,778 | 36,005 | 17,658 | 36,385 | 17,448 | 36,189 |
| Physical sciences .. ...... . | 22,918 | 4,034 | 23,308 | 4,074 | 24,040 | 4,159 | 25,213 | 4,262 | 25,874 | 4,613 | 26,622 | 4,573 | 27,697 | 5,013 |
| Doctorate-granting ... . . | 22,254 | 3,139 | 22,600 | 3,180 | 23,330 | 3,169 | 24,492 | 3,235 | 25,149 | 3,264 | 25,967 | 3,348 | 27,074 | 3,528 |
| Master's granting ........... | 664 | 895 | 708 | 894 | 710 | 990 | 721 | 1,027 | 725 | 1,349 | 655 | 1,225 | 623 | 1,485 |
| Environmental sciences .... | 10,969 | 3,239 | 11,038 | 3,384 | 11,436 | 3,738 | 12,089 | 3,520 | 11,714 | 4,088 | 11,390 | 4,351 | 11,265 | 4,077 |
| Doctorate-granting .......... | 10,265 | 2,530 | 10,491 | 2,572 | 10,873 | 2,884 | 11,466 | 2,801 | 11,283 | 3,043 | 10,918 | 3,334 | 10,909 | 3,156 |
| Master's granting ........... | 704 | 709 | 547 | 812 | 563 | 854 | 623 | 719 | 431 | 1,045 | 472 | 1,017 | 356 | 921 |
| Mathematical sciences ........ | 9,902 | 5,458 | 10,154 | 5,761 | 10,823 | 6,376 | 10,971 | 6,472 | 11,432 | 6,400 | 11,963 | 6,144 | 12,456 | 5,923 |
| Doctorate-granting .......... | 9,368 | 4,257 | 9,680 | 4,324 | 10,174 | 4,584 | 10,312 | 4,560 | 10,613 | 4,454 | 11,168 | 4,100 | 11,767 | 3,911 |
| Master's granting ........... | 534 | 1,201 | 474 | 1,437 | 649 | 1,792 | 659 | 1,912 | 819 | 1,946 | 795 | 2,044 | 689 | 2,012 |
| Computer sciences .. . . | 6,587 | 6,991 | 7,445 | 8,992 | 9,171 | 10,641 | 10,687 | 12,929 | 11,328 | 14,036 | 13,928 | 15,594 | 15,071 | 15,655 |
| Doctorate-granting ... . . | 5,900 | 5,484 | 6,465 | 6,676 | 7,908 | 7,668 | 9,267 | 9,028 | 10,108 | 10,258 | 12,433 | 11,390 | 13,504 | 11,848 |
| Master's granting ........... | 687 | 1,507 | 980 | 2,316 | 1,263 | 2,973 | 1,420 | 3,901 | 1,220 | 3,778 | 1,495 | 4,204 | 1,567 | 3,807 |
| Life sciences ................. | 72,409 | 30,095 | 72,241 | 30,883 | 70,254 | 32,635 | 70,111 | 33,591 | 70,341 | 35,207 | 70,177 | 36,477 | 70,929 | 37,398 |
| Doctorate-granting .......... | 67,711 | 22,949 | 67,195 | 23,713 | 65,653 | 25,050 | 65,098 | 26,032 | 66,044 | 26,372 | 66,112 | 27,177 | 67,205 | 28,713 |
| Master's granting ........... | 4,698 | 7,146 | 5,046 | 7,170 | 4,601 | 7,585 | 5,013 | 7,559 | 4,297 | 8,835 | 4,065 | 9,300 | 3,724 | 8,685 |
| Psychology .................. | 26,692 | 13,944 | 26,725 | 13,966 | 25,818 | 14,280 | 26,749 | 14,355 | 27,063 | 17,242 | 26,657 | 17,404 | 27,085 | 16,818 |
| Doctorate-granting .......... | 21,580 | 7,804 | 21,544 | 7,508 | 21,103 | 7,979 | 21,309 | 7,739 | 21,578 | 8,413 | 21,524 | 9,036 | 22,007 | 8,752 |
| Master's granting ........... | 5,112 | 6,140 | 5,181 | 6,458 | 4,715 | 6,301 | 5,440 | 6,616 | 5,485 | 8,829 | 5,133 | 8,368 | 5,078 | 8,066 |
| Social sciences ............. | 56,575 | 38,203 | 55,829 | 37,361 | 53,516 | 37,501 | 52,677 | 36,574 | 52,987 | 37,255 | 52,130 | 37,275 | 52,999 | 38,421 |
| Doctorate-granting .......... | 51,518 | 28,767 | 51,402 | 28,245 | 49,211 | 29,032 | 48,080 | 28,233 | 47,186 | 27,031 | 47,085 | 27,046 | 47,589 | 27,208 |
| Master's granting ........... | 5,057 | 9,436 | 4,427 | 9,116 | 4,305 | 8,469 | 4,597 | 8,341 | 5,801 | 10,224 | 5,045 | 10,229 | 5,410 | 11,213 |
| Total engineering ............... | 43,107 | 31,977 | 46,257 | 34,222 | 50,239 | 34,355 | 55,193 | 37,962 | 56,581 | 40,239 | 57,488 | 42,453 | 61,732 | 43,562 |
| Doctorate-granting .......... | 41,939 | 28,204 | 44,817 | 29,556 | 48,687 | 29,491 | 53,516 | 32,895 | 54,757 | 33,515 | 55,940 | 35,444 | 59,925 | 37,107 |
| Master's granting ........... | 1,168 | 3,773 | 1,440 | 4,666 | 1,552 | 4,864 | 1,677 | 5,067 | 1,824 | 6,724 | 1,548 | 7,009 | 1,807 | 6,455 |

SOURCE: National Science Foundation, *Academic Science/Engineering. Graduate Enrollment and Support, Fall 1986* (forthcoming)

## Appendix table 2-6. S/E postdoctorates in doctorate-granting institutions by field: 1980-86

| Field | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Average annual Percent change 1985-86 | Average annual Percent change 1980-86 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Percent | Percent |
| Total sciences and engineering | 18,411 | 19,646 | 19,366 | 20,761 | 21,587 | 22,598 | 24,136 | 6.8 | 4.6 |
| Total sciences | 17,433 | 18,606 | 18,388 | 19,659 | 20,392 | 21,249 | 22,716 | 6.9 | 4.5 |
| Physical sciences | 4,264 | 4,462 | 4,281 | 4,444 | 4,386 | 4,517 | 4,813 | 6.6 | 2.0 |
| Environmental sciences | 308 | 339 | 335 | 415 | 488 | 375 | 418 | 11.5 | 5.2 |
| Mathematical sciences | 162 | 133 | 194 | 170 | 203 | 226 | 201 | -11.1 | 3.7 |
| Computer sciences | 43 | 34 | 46 | 82 | 63 | 74 | 74 | 0.0 | 9.5 |
| Life sciences | 11,743 | 12,855 | 12,725 | 13,756 | 14,473 | 15,191 | 16,328 | 7.5 | 5.6 |
| Psychology | 475 | 471 | 520 | 435 | 422 | 498 | 526 | 5.6 | 1.7 |
| Social sciences | 438 | 332 | 287 | 357 | 357 | 368 | 356 | -3.3 | -3.4 |
| Total engineering | 978 | 1,040 | 978 | 1 102 | 1,195 | 1,349 | 1,420 | 5.3 | 6.4 |

SOURCE: National Science Foundation, *Academic Science/Engineering Graduate Enrollment and Support: Fall 1986* (forthcoming)

See figures 2-1 and 2-20.

Science & Engineering Indicators—1987

## Appendix table 2-7. S/E graduate students in all institutions, by gender: 1980-86

| Field | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Average annual percent change 1985-86 | Average annual percent change 1980-86 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Percent | Percent |
| Total sciences and engineering | 383,100 | 391,640 | 398,982 | 413,355 | 426,399 | 434,622 | 446,102 | 2.6 | 2.6 |
| Male | 249,328 | 249,471 | 252,179 | 259,961 | 265,711 | 270,958 | 277,337 | 2.4 | 1.8 |
| Female | 133,772 | 142,169 | 146,803 | 153,394 | 160,688 | 163,664 | 168,765 | 3.1 | 3.9 |
| Total sciences | 308,016 | 311,161 | 314,388 | 320,200 | 329,579 | 334,681 | 340,808 | 1.8 | 1.7 |
| Male | 180,747 | 176,923 | 176,558 | 177,168 | 180,042 | 182,997 | 185,277 | 1.2 | 0.4 |
| Female | 127,269 | 134,238 | 137,830 | 143,032 | 149,537 | 151,684 | 155,531 | 2.5 | 3.4 |
| Physical sciences | 26,952 | 27,382 | 28,199 | 29,475 | 30,487 | 31,194 | 32,710 | 4.9 | 3.3 |
| Male | 22,352 | 22,366 | 22,776 | 23,594 | 24,201 | 24,636 | 25,712 | 4.4 | 2.4 |
| Female | 4,600 | 5,016 | 5,423 | 5,881 | 6,285 | 6,559 | 6,998 | 6.7 | 7.2 |
| Environmental sciences | 14,208 | 14,422 | 15,174 | 15,609 | 15,803 | 15,741 | 15,342 | -2.5 | 1.3 |
| Male | 10,940 | 10,945 | 11,393 | 11,634 | 11,849 | 11,724 | 11,328 | -3.4 | 0.6 |
| Female | 3,268 | 3,477 | 3,781 | 3,975 | 3,954 | 4,017 | 4,014 | -0.1 | 3.5 |
| Mathematical sciences | 15,360 | 15,915 | 17,199 | 17,443 | 17,831 | 18,106 | 18,379 | 1.5 | 3.0 |
| Male | 11,272 | 11,419 | 12,109 | 12,222 | 12,562 | 12,574 | 12,795 | 1.8 | 2.1 |
| Female | 4,088 | 4,496 | 5,090 | 5,221 | 5,269 | 5,532 | 5,584 | 0.9 | 5.3 |
| Computer sciences | 13,578 | 16,437 | 19,812 | 23,616 | 25,364 | 29,522 | 30,726 | 4.1 | 14.6 |
| Male | 10,491 | 12,228 | 14,366 | 16,968 | 18,659 | 22,326 | 23,266 | 4.2 | 14.2 |
| Female | 3,087 | 4,209 | 5,446 | 6,648 | 6,705 | 7,196 | 7,460 | 3.7 | 15.8 |
| Life sciences | 102,504 | 103,124 | 102,889 | 103,702 | 105,548 | 106,653 | 108,328 | 1.6 | 0.9 |
| Male | 51,062 | 49,353 | 47,646 | 46,754 | 46,759 | 46,734 | 47,043 | 0.7 | -1.4 |
| Female | 51,442 | 53,771 | 55,243 | 56,948 | 58,788 | 59,919 | 61,285 | 2.3 | 3.0 |
| Psychology | 40,636 | 40,691 | 40,098 | 41,104 | 44,305 | 44,060 | 43,903 | -0.4 | 1.3 |
| Male | 19,036 | 17,902 | 16,980 | 16,706 | 17,170 | 16,609 | 16,088 | -3.1 | -2.8 |
| Female | 21,600 | 22,789 | 23,118 | 24,398 | 27,135 | 27,452 | 27,815 | 1.3 | 4.3 |
| Social sciences | 94,778 | 93,190 | 91,017 | 89,251 | 90,242 | 89,405 | 91,420 | 2.3 | -0.6 |
| Male | 55,594 | 52,710 | 51,288 | 49,290 | 48,842 | 48,396 | 49,045 | 1.3 | -2.1 |
| Female | 39,184 | 40,480 | 39,729 | 39.961 | 41,400 | 41.009 | 42,375 | 3.3 | 1.3 |
| Total engineering | 75,084 | 80,479 | 84,594 | 93,155 | 96.820 | 99,941 | 105,294 | 5.4 | 5.8 |
| Male | 68,581 | 72,548 | 75,621 | 82,793 | 85,669 | 87,961 | 92,060 | 4.7 | 5.0 |
| Female | 6,503 | 7,931 | 8,973 | 10.362 | 11,151 | 11,980 | 13,234 | 10.5 | 12.6 |

SOURCE: National Science Foundation, *Academic Science/Engineering Graduate Enrollment and Support: Fall 1986* (forthcoming)

See figure 2-1.

Science & Engineering Indicators—1987

**Appendix table 2-8. Region of origin of foreign students in the United States: 1974/75 to 1985/86**

| Academic year | Total[1] | Africa | Europe | Latin America | Middle East | North America | Oceania | South and East Asia |
|---|---|---|---|---|---|---|---|---|
| 1974/75 | 154,580 | 18.400 | 13,740 | 26,270 | 23,910 | 8,630 | 2,650 | 58.460 |
| 1975/76 | 179,340 | 25,290 | 14,400 | 29,820 | 32,590 | 9.720 | 2,740 | 64,540 |
| 1976/77 | 203,070 | 25,860 | 16,700 | 37,240 | 38,490 | 11,420 | 3,150 | 70.020 |
| 1977/78 | 235,510 | 29,560 | 19,310 | 38.840 | 57,210 | 12,920 | 3,810 | 73,760 |
| 1978/79 | 263,940 | 33,990 | 21,690 | 41,120 | 70,430 | 15,520 | 4,150 | 76,850 |
| 1979/80 | 286,340 | 36,180 | 22,570 | 42,280 | 83,700 | 15,570 | 4,[illegible]40 | 81,730 |
| 1980/81 | 311,880 | 38,180 | 25,330 | 49,810 | 84,710 | 14,790 | 4,160 | 94,640 |
| 1981/82 | 326,300 | 41,660 | 28,990 | 55,360 | 74,390 | 15,460 | 4,000 | 106,160 |
| 1982/83 | 336,990 | 42,690 | 31,570 | 56,810 | 67,280 | 14,570 | 4,040 | 119,650 |
| 1983/84 | 338,890 | 41,690 | 31,860 | 52,350 | 60,660 | 15,670 | 4,090 | 132,270 |
| 1984/85 | 342,110 | 39,520 | 33,350 | 48,560 | 56,580 | 15,960 | 4,190 | 143,680 |
| 1985/86 | 343,777 | 34,190 | 34,310 | 45,480 | 52,720 | 16,030 | 4,030 | 156,830 |
| | Percentage distribution | | | | | | | |
| 1974/75 | 100.0 | 11.9 | 8.9 | 17.0 | 15.5 | 5.6 | 1.7 | 37.8 |
| 1975/76 | 100.0 | 14.1 | 8.1 | 16.6 | 18.2 | 5.4 | 1.5 | 36.0 |
| 1976/77 | 100.0 | 12.7 | 8.2 | 18.4 | 18.9 | 5.6 | 1.6 | 34.5 |
| 1977/78 | 100.0 | 12.6 | 8.2 | 16.5 | 24.3 | 5.5 | 1.6 | 31.3 |
| 1978/79 | 100.0 | 12.9 | 8.2 | 15.6 | 26.6 | 5.9 | 1.6 | 29.1 |
| 1979/80 | 100.0 | 12.6 | 7.9 | 14.8 | 29.2 | 5.4 | 1.4 | 28.6 |
| 1980/81 | 100.0 | 12.2 | 8.1 | 16.0 | 27.2 | 4.7 | 1.3 | 30.4 |
| 1981/82 | 100.0 | 12.8 | 8.9 | 17.0 | 22.8 | 4.7 | 1.2 | 32.5 |
| 1982/83 | 100.0 | 12.7 | 9.4 | 16.9 | 19.9 | 4.3 | 1.2 | 35.5 |
| 1983/84 | 100.0 | 12.3 | 9.4 | 15.5 | 17.9 | 4.6 | 1.2 | 39.0 |
| 1984/85 | 100.0 | 11.6 | 9.7 | 14.2 | 16.5 | 4.7 | 1.2 | 42.0 |
| 1985/86 | 100.0 | 9.9 | 10.0 | 13.2 | 15.3 | 4.7 | 1.2 | 45.6 |

[1] Details may not add to totals, which include foreign students of unknown origin.

SOURCE: Institute of International Education. *Open Doors* (annual, 1972-1986. IIE. 809 United Nations Plaza. New York. N.Y 10017)

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## Appendix table 2-9. Doctorates from U.S. universities: 1960-86

| Year | Total | Non-S/E | Total S/E | Total sciences | Total engineering | Physical sciences | Mathematical sciences | Computer sciences | Life sciences | Psychology | Social sciences |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | 9,733 | 3,470 | 6,263 | 5,469 | 794 | 1,861 | 291 | NA | 1,660 | 772 | 885 |
| 1961 | 10,413 | 3,692 | 6,721 | 5,781 | 940 | 1,993 | 332 | NA | 1,682 | 820 | 954 |
| 1962 | 11,500 | 4,062 | 7,438 | 6,222 | 1,216 | 2,097 | 388 | NA | 1,867 | 856 | 1,014 |
| 1963 | 12,728 | 4,509 | 8,219 | 6,862 | 1,357 | 2,427 | 483 | NA | 1,976 | 890 | 1,086 |
| 1964 | 14,325 | 5,101 | 9,224 | 7,560 | 1,664 | 2,527 | 588 | NA | 2,219 | 1,013 | 1,213 |
| 1965 | 16,340 | 5,864 | 10,476 | 8,402 | 2,074 | 2,865 | 685 | NA | 2,539 | 954 | 1,359 |
| 1966 | 17,949 | 6,491 | 11,458 | 9,157 | 2,301 | 3,059 | 769 | NA | 2,711 | 1,139 | 1,479 |
| 1967 | 20,403 | 7,421 | 12,982 | 10,378 | 2,604 | 3,503 | 830 | NA | 2,966 | 1,295 | 1,784 |
| 1968 | 22,936 | 8,488 | 14,448 | 11,593 | 2,855 | 3,681 | 971 | NA | 3,511 | 1,464 | 1,966 |
| 1969 | 25,743 | 9,704 | 16,039 | 12,774 | 3,265 | 3,935 | 1,070 | NA | 3,815 | 1,766 | 2,188 |
| 1970 | 29,498 | 11,755 | 17,743 | 14,309 | 3,434 | 4,403 | 1,225 | NA | 4,165 | 1,890 | 2,626 |
| 1971 | 31,867 | 12,918 | 18,949 | 15,451 | 3,498 | 4,501 | 1,238 | NA | 4,557 | 2,145 | 3,010 |
| 1972 | 33,041 | 14,034 | 19,007 | 15,504 | 3,503 | 4,257 | 1,281 | NA | 4,454 | 2,279 | 3,233 |
| 1973 | 33,755 | 14,754 | 19,001 | 15,637 | 3,364 | 4,078 | 1,233 | NA | 4,503 | 2,458 | 3,365 |
| 1974 | 33,047 | 14,734 | 18,313 | 15,166 | 3,147 | 3,765 | 1,211 | NA | 4,304 | 2,598 | 3,288 |
| 1975 | 32,951 | 14,593 | 18,358 | 15,356 | 3,002 | 3,710 | 1,147 | NA | 4,402 | 2,751 | 3,346 |
| 1976 | 32,946 | 15,082 | 17,864 | 15,030 | 2,834 | 3,506 | 1,003 | NA | 4,361 | 2,883 | 3,277 |
| 1977 | 31,716 | 14,299 | 17,417 | 14,774 | 2,643 | 3,415 | 933 | 31 | 4,266 | 2,990 | 3,139 |
| 1978 | 30,875 | 13,827 | 17,048 | 14,625 | 2,423 | 3,234 | 838 | 121 | 4,369 | 3,055 | 3,008 |
| 1979 | 31,237 | 13,992 | 17,245 | 14,755 | 2,490 | 3,320 | 769 | 210 | 4,501 | 3,091 | 2,864 |
| 1980 | 31,017 | 13,818 | 17,199 | 14,720 | 2,479 | 3,149 | 744 | 218 | 4,715 | 3,098 | 2,796 |
| 1981 | 31,353 | 13,720 | 17,633 | 15,105 | 2,528 | 3,210 | 728 | 232 | 4,786 | 3,358 | 2,791 |
| 1982 | 31,096 | 13,470 | 17,626 | 14,980 | 2,646 | 3,351 | 720 | 220 | 4,841 | 3,158 | 2,690 |
| 1983 | 31,216 | 13,284 | 17,932 | 15,151 | 2,781 | 3,439 | 701 | 286 | 4,749 | 3,308 | 2,666 |
| 1984 | 31,277 | 13,208 | 18,069 | 15,156 | 2,913 | 3,459 | 698 | 295 | 4,869 | 3,223 | 2,609 |
| 1985 | 31,211 | 12,770 | 18,262 | 15,095 | 3,167 | 3,534 | 688 | 311 | 4,882 | 3,072 | 2,608 |
| 1986 | 31,770 | 12,978 | 18,792 | 15,416 | 3,376 | 3,679 | 730 | 399 | 4,790 | 3,071 | 2,747 |

Note: NA – Available

SOURCE: National Science Foundation, Division of Science Resources Studies, Science and Engineering Education Sector Studies Group, unpublished data

See figure 2-3 and table O-2 in Overview.

## Appendix table 2-10. Academic degrees awarded by degree level, S/E and non- S/E, and gender: 1960-86

| | Bachelors | | | | | Masters | | | | | Doctorates | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | | | Percent | | Number | | | Percent | | Number | | | Percent | |
| Year | Total | S/E | Female | S/E | Female | Total | S/E | Female | S/E | Female | Total | S/E | Female | S/E | Female |
| 1960 | 394,889 | 120,937 | 19,362 | 31 | 16 | 74,497 | 20,012 | 2,074 | 27 | 10 | 9,733 | 6,263 | 443 | 64 | 7 |
| 1961 | 401,784 | 121,660 | 20,595 | 30 | 17 | 78,269 | 22,786 | 2,464 | 29 | 11 | 10,413 | 6,721 | 494 | 65 | 7 |
| 1962 | 420,485 | 127,469 | 23,485 | 30 | 18 | 84,889 | 25,146 | 2,812 | 30 | 11 | 11,500 | 7,438 | 537 | 65 | 7 |
| 1963 | 450,592 | 135,964 | 27,099 | 30 | 20 | 91,418 | 27,367 | 3,1[illegible]4 | 30 | 12 | 12,728 | 8,219 | 598 | 65 | 7 |
| 1964 | 502,104 | 153,361 | 32,473 | 31 | 21 | 101,222 | 30,271 | 3,567 | 30 | 12 | 14,325 | 9,224 | 692 | 64 | 8 |
| 1965 | 538,930 | 164,936 | 36,213 | 31 | 22 | 112,195 | 33,835 | 4,082 | 30 | 12 | 16,340 | 10,476 | 744 | 64 | 7 |
| 1966 | 555,613 | 173,471 | 39,482 | 31 | 23 | 140,772 | 38,083 | 4,882 | 27 | 13 | 17,949 | 11,458 | 909 | 64 | 8 |
| 1967 | 594,862 | 187,849 | 44,002 | 32 | 23 | 157,892 | 41,800 | 5,717 | 26 | 14 | 20,403 | 12,982 | 1,086 | 64 | 8 |
| 1968 | 671,591 | 212,174 | 53,463 | 32 | 25 | 177,150 | 45,425 | 6,512 | 26 | 14 | 22,936 | 14,448 | 1,298 | 63 | 9 |
| 1969 | 769,683 | 244,519 | 63,196 | 32 | 26 | 194,414 | 48,425 | 7,314 | 25 | 15 | 25,743 | 16,039 | 1,483 | 62 | 9 |
| 1970 | 833,322 | 264,122 | 68,878 | 32 | 26 | 209,387 | 49,318 | 8,577 | 24 | 17 | 29,498 | 17,743 | 1,626 | 60 | 9 |
| 1971 | 884,386 | 271,176 | 72,996 | 31 | 27 | 231,486 | 50,624 | 8,658 | 22 | 17 | 31,867 | 18,949 | 1,941 | 59 | 10 |
| 1972 | 937,884 | 281,228 | 77,671 | 30 | 28 | 252,774 | 53,567 | 9,557 | 21 | 19 | 33,041 | 19,007 | 2,103 | 58 | 11 |
| 1973 | 980,707 | 295,391 | 83,839 | 30 | 28 | 264,525 | 54,234 | 9,760 | 21 | 18 | 33,755 | 19,001 | 2,450 | 56 | 13 |
| 1974 | 1,008,654 | 305,062 | 91,793 | 30 | 30 | 278,259 | 54,175 | 10,545 | 19 | 19 | 33,047 | 18,313 | 2,607 | 55 | 14 |
| 1975 | 987,922 | 294,920 | 93,342 | 30 | 32 | 293,651 | 53,825 | 11,005 | 18 | 20 | 32,951 | 18,358 | 2,836 | 56 | 15 |
| 1976 | 997,504 | 292,174 | 95,597 | 29 | 33 | 313,001 | 54,747 | 12,072 | 17 | 22 | 32,946 | 17,864 | 2,981 | 54 | 17 |
| 1977 | 993,008 | 288,543 | 97,453 | 29 | 34 | 318,241 | 56,731 | 13,154 | 18 | 23 | 31,716 | 17,4[illegible] | 3,106 | 55 | 18 |
| 1978 | 997,165 | 288,167 | 100,060 | 29 | 35 | 312,815 | 56,237 | 13,690 | 18 | 24 | 30,875 | 17,048 | 3,313 | 55 | 19 |
| 1979 | 1,000,562 | 288,625 | 102,292 | 29 | 35 | 302,075 | 54,456 | 14,040 | 18 | 26 | 31,237 | 17,245 | 3,583 | 55 | 21 |
| 1980 | 1,010,777 | 291,983 | 105,974 | 29 | 36 | 299,095 | 54,391 | 14,383 | 18 | 26 | 31,017 | 17,199 | 3,801 | 55 | [illegible] |
| 1981 | 1,019,246 | 294,867 | 108,442 | 29 | 37 | 296,798 | 54,811 | 15,014 | 18 | 27 | 31,353 | 17,633 | 4,023 | 56 | [illegible] |
| 1982 | 1,036,597 | 302,118 | 113,161 | 29 | 37 | 296,580 | 57,025 | 15,976 | 20 | 28 | 31,096 | 7,626 | 4,143 | 57 | 24 |
| 1983 | 1,054,242 | 307,225 | 115,611 | 29 | 38 | 290,931 | 58,868 | 17,081 | 20 | 29 | 31,216 | 17,93[illegible] | 4,468 | 57 | 25 |
| 1984 | 986,345 | 314,656 | 118,016 | 32 | 38 | 285,462 | 59,569 | 17,675 | 21 | 30 | 31,277 | 18,069 | 4,568 | 58 | 25 |
| 1985 | 1,066,439 | 321,739 | 121,439 | 30 | 38 | 287,213 | 61,278 | 18,298 | 23 | 30 | 31,211 | 18,262 | 4,655 | 59 | 25 |
| 1986 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 31,770 | 18,792 | 4,906 | 59 | 26 |

SOURCE Bachelor and Masters degrees, 1960-1980 National Science Foundation, *Science and Engineering Degrees 1950-1980* (NSF 82 307). Bachelor and Masters degrees 1980 85, and all Ph.D s National Science F[illegible]ndation, Division of Science Resources Studies Science and Engineering Education Sector Studies Group, unpublished tabulations

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## Appendix table 2-11. Median total years from receipt of baccalaureate to earning the doctorate: 1960-84

| Field of doctorate | Year of doctorate | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1962 | 1964 | 1966 | 1968 | 1970 | 1972 | 1974 | 1976 | 1978 | 1980 | 1982 | 1984 |
| Total Ph.D.s | 8.77 | 8.83 | 8.37 | 8.16 | 8.11 | 7.88 | 8.19 | 8.51 | 8.64 | 8.90 | 9.27 | 9.56 | 10.00 |
| Men | 8.54 | 8.57 | 8.09 | 7.91 | 7.88 | 7.64 | 8.00 | 8.34 | 8.37 | 8.55 | 8.77 | 8.99 | 9.31 |
| Women | 12.16 | 12.01 | 11.92 | 10.86 | 10.29 | 9.63 | 9.68 | 9.41 | 9.72 | 10.07 | 10.53 | 10.99 | 11.60 |
| Physical sciences | 6.49 | 6.51 | 6.18 | 6.04 | 6.02 | 6.11 | 6.53 | 6.78 | 6.74 | 6.98 | 6.85 | 6.89 | 7.20 |
| Men | 6.48 | 6.53 | 6.17 | 6.04 | 6.00 | 6.08 | 6.52 | 6.79 | 6.74 | 7.01 | 6.88 | 6.89 | 7.23 |
| Women | 7.08 | 6.25 | 6.50 | 6.17 | 6.46 | 6.71 | 6.65 | 6.58 | 6.65 | 6.77 | 6.65 | 6.87 | 7.05 |
| Engineering | 7.36 | 7.07 | 6.97 | 6.99 | 7.07 | 6.93 | 7.46 | 7.62 | 7.46 | 7.50 | 7.63 | 7.97 | 7.99 |
| Men | 7.36 | 7.05 | 6.97 | 6.98 | 7.07 | 6.92 | 7.46 | 7.63 | 7.46 | 7.50 | 7.65 | 8.00 | 8.02 |
| Women | 12.00 | 10.00 | 7.50 | 7.83 | 6.50 | 8.00 | 7.50 | 7.00 | 7.57 | 7.40 | 6.58 | 7.62 | 7.37 |
| Life sciences | 7.96 | 7.82 | 7.40 | 7.34 | 7.13 | 6.63 | 6.99 | 7.20 | 7.28 | 7.32 | 7.37 | 7.61 | 8.10 |
| Men | 7.89 | 7.73 | 7.30 | 7.32 | 7.15 | 6.61 | 6.97 | 7.22 | 7.27 | 7.21 | 7.26 | 7.50 | 8.04 |
| Women | 8.91 | 8.90 | 8.48 | 7.50 | 7.02 | 6.77 | 7.10 | 7.12 | 7.34 | 7.83 | 7.76 | 7.94 | 8.51 |
| Social sciences | 8.75 | 9.02 | 8.18 | 7.64 | 7.70 | 7.31 | 7.47 | 7.72 | 7.75 | 8.13 | 8.59 | 9.15 | 9.68 |
| Men | 8.62 | 8.86 | 8.00 | 7.45 | 7.58 | 7.22 | 7.35 | 7.72 | 7.69 | 8.05 | 8.45 | 8.97 | 9.56 |
| Women | 9.81 | 10.44 | 9.70 | 9.27 | 8.34 | 7.85 | 8.03 | 7.73 | 7.94 | 8.31 | 8.87 | 9.54 | 9.92 |
| Humanities | 10.05 | 10.32 | 9.91 | 9.83 | 9.47 | 9.07 | 8.99 | 9.30 | 9.70 | 10.18 | 10.61 | 11.16 | 11.48 |
| Men | 9.92 | 10.06 | 9.71 | 9.55 | 9.26 | 8.88 | 8.86 | 9.21 | 9.58 | 9.95 | 10.29 | 10.79 | 11.18 |
| Women | 11.67 | 12.14 | 11.19 | 11.08 | 10.45 | 9.73 | 9.44 | 9.52 | 9.95 | 10.53 | 11.21 | 11.70 | 11.94 |
| Education | 12.89 | 12.76 | 13.50 | 14.25 | 13.94 | 12.68 | 12.53 | 12.38 | 12.65 | 12.71 | 13.15 | 13.60 | 14.63 |
| Men | 12.21 | 12.31 | 13.00 | 13.90 | 13.33 | 12.28 | 12.14 | 12.14 | 12.52 | 12.39 | 12.87 | 13.16 | 14.19 |
| Women | 26.61 | 23.00 | 28.29 | 23.75 | 23.50 | 14.94 | 14.45 | 13.35 | 13.00 | 13.31 | 13.53 | 14.16 | 15.09 |
| Professional fields | 11.80 | 10.84 | 10.95 | 10.77 | 10.92 | 10.15 | 9.72 | 9.79 | 10.31 | 10.73 | 11.05 | 11.58 | 12.23 |
| Men | 10.63 | 10.18 | 10.47 | 10.05 | 10.55 | 9.79 | 9.27 | 9.63 | 10.07 | 10.45 | 10.93 | 11.59 | 11.78 |
| Women | 47.51 | 20.37 | 15.50 | 28.42 | 19.99 | 21.63 | 17.21 | 12.31 | 11.27 | 11.35 | 11.74 | 11.56 | 13.29 |

SOURCE: National Research Council. *Doctorate Recipients from U.S Universities*, various issues

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## Appendix table 2-12. Enrollment and source of support of full-time S/E graduate students in doctorate-granting institutions: 1980-86

| Field and support | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Average annual percent change 1985-86 | Average annual percent change 1980-86 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Percent | |
| Total science and engineering | 230.535 | 234,194 | 236.939 | 243.540 | 246.718 | 251.147 | 259.980 | 3 5 | 2.0 |
| Federal | 52.939 | 50.897 | 47.206 | 47.415 | 47.687 | 48.964 | 51,367 | 4.9 | - 0.5 |
| Institutional support | 86.715 | 90.261 | 93.244 | 96.108 | 100.001 | 102.325 | 107.479 | 5.0 | 3.6 |
| Other outside support | 21.066 | 22.382 | 23.630 | 24.430 | 24.535 | 26.427 | 26.718 | 1.1 | 4.0 |
| Self support | 69.815 | 70.654 | 72.859 | 75.587 | 74.495 | 73.431 | 74.416 | 1.3 | 1.1 |
| Total sciences | 188.596 | 189.377 | 188.252 | 190.024 | 191.961 | 195.207 | 200.055 | 2.5 | 1.0 |
| Federal | 41.832 | 39.974 | 36.201 | 35.499 | 36.179 | 37,771 | 39.002 | 3.3 | 1.2 |
| Institutional support | 74.081 | 76.161 | 78.075 | 79.869 | 82.774 | 84.049 | 87.502 | 4.1 | 2.8 |
| Other outside support | 14.914 | 15.500 | 15.993 | 16.463 | 15.991 | 16.911 | 16.519 | -2.3 | 1.7 |
| Self support | 57.769 | 57.742 | 57.983 | 58.193 | 57.017 | 56.476 | 57.032 | 1.0 | -0.2 |
| Physical sciences | 22.254 | 22.600 | 23.330 | 24.492 | 25.149 | 25.967 | 27.074 | 4.3 | 3.3 |
| Federal | 7.655 | 7.899 | 7.644 | 8.050 | 8.551 | 8.723 | 9.434 | 8.2 | 3.5 |
| Institutional support | 11.928 | 11.924 | 12.581 | 13.160 | 13.283 | 13.565 | 14.018 | 3 3 | 2.7 |
| Other outside support | 1.307 | 1.416 | 1.740 | 1,688 | 1.791 | 2.046 | 1.907 | 6 8 | 6.5 |
| Self support | 1.364 | 1.361 | 1.365 | 1.594 | 1.524 | 1.633 | 1.715 | 5 0 | 3 9 |
| Environmental sciences | 10.265 | 10.491 | 10.873 | 11.466 | 11.283 | 10.918 | 10.909 | -0.1 | 1.0 |
| Federal | 3.369 | 2.965 | 2,808 | 2.845 | 2,822 | 2.939 | 3.015 | 2.6 | -1.8 |
| Institutional support | 3.648 | 3.916 | 4,097 | 4.075 | 4.179 | 3.983 | 4,166 | 4.6 | 2.2 |
| Other outside support | 1,042 | 1.129 | 1,199 | 1.259 | 1.224 | 1.385 | 1.227 | -11.4 | 2.8 |
| Self support | 2.206 | 2.481 | 2.769 | 3.287 | 3.058 | 2.611 | 2.501 | 4 2 | 2.1 |
| Mathematical sciences | 9.368 | 9.680 | 10.174 | 10.312 | 10.613 | 11.168 | 11,767 | 5.4 | 3.9 |
| Federal | 842 | 782 | 802 | 747 | 755 | 930 | 992 | 6.7 | 2 8 |
| Institutional support | 6.340 | 6.457 | 6.827 | 7.119 | 7.389 | 7.766 | 8.182 | 5.4 | 4.3 |
| Other outside support | 519 | 526 | 536 | 507 | 626 | 543 | 587 | 8.1 | 2.1 |
| Self support | 1,667 | 1.915 | 2.009 | 1.939 | 1.843 | 1.929 | 2.006 | 4.0 | 3.1 |
| Computer sciences | 5.900 | 6.465 | 7.908 | 9.267 | 10.108 | 12.433 | 13.504 | 8.6 | 14.8 |
| Federal | 879 | 944 | 973 | 1.045 | 1.215 | 1.568 | 1.818 | 15.9 | 12.9 |
| Institutional support | 1.961 | 2.314 | 2.579 | 3.072 | 3.486 | 4.089 | 4.315 | 5.5 | 14.0 |
| Other outside support | 602 | 598 | 670 | 689 | 705 | 1.264 | 1.424 | 12.7 | 15.4 |
| Self support | 2.458 | 2.609 | 3.686 | 4.461 | 4.702 | 5.512 | 5.947 | 7.9 | 15 9 |
| Agricultural sciences | 9.591 | 9.630 | 9.500 | 9.397 | 9.327 | 8.723 | 8.858 | 1.5 | -1.3 |
| Federal | 1.778 | 1.710 | 1.654 | 1.510 | 1.350 | 1.504 | 1.603 | 6 6 | -1.7 |
| Institutional support | 3.359 | 3.448 | 3,444 | 3.576 | 3.821 | 3.369 | 3.517 | 4.4 | 0.8 |
| Other outside support | 2.023 | 2.116 | 2.008 | 2.090 | 1.942 | 1.852 | 1,755 | -5.2 | -2.3 |
| Self support | 2.431 | 2.356 | 2,394 | 2.221 | 2.214 | 1.998 | 1.983 | -0.8 | -3.3 |
| Biological sciences | 35.817 | 35.454 | 35.226 | 35.148 | 35.833 | 35.983 | 36.916 | 2.6 | 0.5 |
| Federal | 10.725 | 10.505 | 10.055 | 10.131 | 10.456 | 10.763 | 11.205 | 4.1 | 0.7 |
| Institutional support | 15.546 | 15.674 | 15.796 | 15.843 | 16.419 | 16.465 | 17.101 | 3.9 | 1.6 |
| Other outside support | 2.731 | 2,746 | 3.053 | 3.160 | 3.093 | 3,250 | 3.094 | -4.8 | 2.1 |
| Self support | 6.815 | 6.529 | 6.322 | 6.014 | 5.865 | 5.505 | 5.516 | 0.2 | -3.5 |
| Health sciences | 22.303 | 22.111 | 20.927 | 20.553 | 20.884 | 21.406 | 21.431 | 0.1 | -0.7 |
| Federal | 8.184 | 7.653 | 6,120 | 5.556 | 5.563 | 5.966 | 5,797 | -2.8 | -5.6 |
| Institutional support | 4.437 | 4.314 | 4.612 | 4.673 | 5.114 | 5.380 | 5.653 | 5.1 | 4.1 |
| Other outside support | 1.197 | 1.257 | 1.270 | 1.559 | 1.597 | 1.636 | 1.573 | -3.9 | 4.7 |
| Self support | 8.485 | 8.887 | 8,925 | 8.765 | 8,610 | 8.424 | 8.408 | -0.2 | -0.2 |
| Psychology | 21.580 | 21.544 | 21.103 | 21,309 | 21.578 | 21,524 | 22.007 | 2.2 | 0.3 |
| Federal | 3,189 | 2.895 | 2.283 | 1.980 | 1.942 | 1,958 | 1.893 | 3.3 | -8.3 |
| Institutional support | 7,869 | 8.614 | 8.557 | 8,778 | 9.229 | 9.540 | 9,922 | 4.0 | 3.9 |
| Other outside support | 1.438 | 1.505 | 1,377 | 1,316 | 1.325 | 1.326 | 1,327 | 0.1 | -1.3 |
| Self support | 9.084 | 8.530 | 8.886 | 9.235 | 9.082 | 8,700 | 8.865 | 1.9 | 0.4 |
| Social sciences | 51.518 | 51.402 | 49.211 | 48,080 | 47.186 | 47.085 | 47.589 | 1.1 | -1.3 |
| Federal | 5.211 | 4.621 | 3.862 | 3.635 | 3.525 | 3.420 | 3.245 | 5.1 | -7.6 |
| Institutional support | 18.993 | 19.500 | 19,582 | 19.573 | 19,854 | 19.892 | 20.628 | 3.7 | 1.4 |
| Other outside support | 4.055 | 4.207 | 4.140 | 4.195 | 3.688 | 3,609 | 3.625 | 0.4 | -1.9 |
| Self support | 23.259 | 23.074 | 21.627 | 20.677 | 20.119 | 20.164 | 20.091 | -0.4 | -2.4 |
| Total engineering | 41.939 | 44.817 | 48.687 | 53.516 | 54.757 | 55.940 | 59.925 | 7.1 | 6.1 |
| Federal | 11.107 | 10.923 | 11.005 | 11.916 | 11,508 | 11.193 | 12.365 | 10.5 | 1 8 |
| Institutional support | 12.634 | 14.100 | 15.169 | 16.239 | 17.227 | 18.276 | 19.977 | 9 3 | 7.9 |
| Other outside support | 6.152 | 6.882 | 7.637 | 7.967 | 8,544 | 9.516 | 10.199 | 7.2 | 8.8 |
| Self support | 12.046 | 12.912 | 14.876 | 17.394 | 17.478 | 16.955 | 17.384 | 2.5 | 6 3 |

SOURCE National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support, Fall 1986* (forthcoming)

See figure 2-4

Science & Engineering Indicators—1987

**Appendix table 2-13. Full-time S/E graduate students in doctorate-granting institutions, by field and type of major support: 1980-86**

| Field and type of major support | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Average annual percent change 1985-86 | Average annual percent change 1980-86 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —Percent— | |
| Total sciences and engineering | 230,535 | 234,194 | 236,939 | 243,540 | 246,718 | 251,147 | 259,980 | 3.5 | 2.0 |
| Fellowships and traineeships | 38,901 | 37,653 | 35,979 | 35,388 | 35,734 | 36,888 | 37,345 | 1.2 | 0.7 |
| Research assistantships | 50,781 | 51,946 | 51,828 | 54,146 | 56,946 | 60,448 | 65,560 | 8.5 | 4.3 |
| Teaching assistantships | 51,838 | 53,800 | 56,068 | 57,872 | 59,160 | 60,054 | 60,927 | 1.5 | 2.7 |
| Other types of support | 19,200 | 20,141 | 20,205 | 20,547 | 20,383 | 20,326 | 21,732 | 3.1 | 1.8 |
| Self-support | 69,815 | 70,654 | 72,859 | 75,587 | 74,495 | 73,431 | 74,416 | 1.3 | 1.1 |
| Total engineering | 41,939 | 44,817 | 48,687 | 53,516 | 54,757 | 55,940 | 59,925 | 7.1 | 6.1 |
| Fellowships and traineeships | 4,603 | 5,032 | 5,416 | 5,576 | 5,596 | 5,571 | 5,781 | 3.8 | 3.9 |
| Research assistantships | 13,920 | 14,394 | 14,595 | 15,581 | 16,206 | 17,858 | 20,407 | 14.3 | 6.6 |
| Teaching assistantships | 7,245 | 8,155 | 8,952 | 9,901 | 10,369 | 10,575 | 10,973 | 3.8 | 7.2 |
| Other types of support | 4,117 | 4,324 | 4,848 | 5,064 | 5,108 | 4,981 | 5,380 | 4.0 | 1.8 |
| Self-support | 12,046 | 12,912 | 14,876 | 17,394 | 17,478 | 16,955 | 17,384 | 2.5 | 6.3 |
| Total sciences | 188,596 | 189,377 | 188,252 | 190,024 | 191,961 | 195,207 | 200,055 | 2.5 | 1.0 |
| Fellowships and traineeships | 34,298 | 32,621 | 30,563 | 29,812 | 30,138 | 31,317 | 31,564 | 0.8 | 1.4 |
| Research assistantships | 36,853 | 37,552 | 37,233 | 38,565 | 40,740 | 42,590 | 45,153 | 6.0 | 3.4 |
| Teaching assistantships | 44,593 | 45,645 | 47,116 | 47,971 | 48,791 | 49,479 | 49,954 | 1.0 | 1.9 |
| Other types of support | 15,083 | 15,817 | 15,357 | 15,483 | 15,275 | 15,345 | 16,352 | 2.7 | 1.4 |
| Self-support | 57,769 | 57,742 | 57,983 | 58,193 | 57,017 | 56,476 | 57,032 | 1.0 | 0.2 |
| Physical sciences | 22,254 | 22,600 | 23,330 | 24,492 | 25,149 | 25,967 | 27,074 | 4.3 | 3.3 |
| Fellowships and traineeships | 2,183 | 2,237 | 2,285 | 2,288 | 2,413 | 2,301 | 2,376 | 3.3 | 1.4 |
| Research assistantships | 8,258 | 8,524 | 8,683 | 9,060 | 9,517 | 10,174 | 10,847 | 3.3 | 1.4 |
| Teaching assistantships | 9,894 | 9,976 | 10,361 | 10,898 | 10,979 | 11,148 | 11,329 | 6.6 | 4.6 |
| Other types of support | 555 | 502 | 636 | 652 | 716 | 711 | 807 | 6.9 | 5.5 |
| Self-support | 1,364 | 1,361 | 1,365 | 1,594 | 1,524 | 1,633 | 1,715 | 5.0 | 3.9 |
| Environmental sciences | 10,265 | 10,491 | 10,873 | 11,466 | 11,283 | 10,918 | 10,909 | -0.1 | 1.0 |
| Fellowships and traineeships | 1,107 | 1,095 | 1,140 | 1,147 | 1,117 | 1,139 | 989 | 13.2 | 1.9 |
| Research assistantships | 3,664 | 3,402 | 3,265 | 3,481 | 3,506 | 3,676 | 3,789 | 3.1 | 0.6 |
| Teaching assistantships | 2,563 | 2,541 | 2,737 | 2,752 | 2,743 | 2,541 | 2,554 | 0.5 | 0.1 |
| Other types of support | 725 | 972 | 962 | 799 | 859 | 951 | 1,076 | 6.4 | 5.8 |
| Self-support | 2,206 | 2,481 | 2,769 | 3,287 | 3,058 | 2,611 | 2,501 | 4.2 | 2.1 |
| Mathematical sciences | 9,368 | 9,680 | 10,174 | 10,312 | 10,613 | 11,168 | 11,767 | 5.4 | 3.9 |
| Fellowships and traineeships | 891 | 799 | 788 | 800 | 901 | 992 | 1,007 | 1.5 | 2.1 |
| Research assistantships | 773 | 732 | 822 | 775 | 846 | 969 | 1,017 | 4.4 | 4.6 |
| Teaching assistantships | 5,373 | 5,536 | 5,817 | 6,140 | 6,325 | 6,553 | 6,897 | 5.2 | 4.2 |
| Other types of support | 664 | 698 | 738 | 658 | 698 | 725 | 840 | 7.6 | 3.4 |
| Self-support | 1,667 | 1,915 | 2,009 | 1,939 | 1,843 | 1,929 | 2,006 | 4.0 | 3.1 |
| Computer sciences | 5,900 | 6,465 | 7,908 | 9,267 | 10,108 | 12,433 | 13,504 | 8.6 | 14.8 |
| Fellowships and traineeships | 367 | 473 | 463 | 524 | 612 | 807 | 893 | 10.7 | 16.0 |
| Research assistantships | 1,023 | 1,068 | 1,151 | 1,367 | 1,582 | 2,020 | 2,284 | 13.1 | 14.3 |
| Teaching assistantships | 1,409 | 1,742 | 1,955 | 2,311 | 2,646 | 3,089 | 3,109 | 0.6 | 14.1 |
| Other types of support | 643 | 573 | 653 | 604 | 566 | 1,005 | 1,271 | 11.9 | 10.2 |
| Self-support | 2,458 | 2,609 | 3,686 | 4,461 | 4,702 | 5,512 | 5,947 | 7.9 | 15.9 |
| Agricultural sciences | 9,591 | 9,630 | 9,500 | 9,397 | 9,327 | 8,723 | 8,858 | 1.5 | -.3 |
| Fellowships and traineeships | 772 | 793 | 779 | 759 | 666 | 657 | 649 | 1.2 | 2.9 |
| Research assistantships | 4,484 | 4,647 | 4,558 | 4,509 | 4,612 | 4,308 | 4,612 | 7.1 | 0.5 |
| Teaching assistantships | 888 | 805 | 883 | 879 | 837 | 824 | 752 | 8.7 | 2.7 |
| Other types of support | 1,016 | 1,029 | 886 | 1,029 | 998 | 936 | 862 | 8.0 | 2.4 |
| Self-support | 2,431 | 2,356 | 2,394 | 2,221 | 2,214 | 1,998 | 1,983 | 0.8 | 3.3 |
| Biological sciences | 35,817 | 35,454 | 35,226 | 35,148 | 35,833 | 35,983 | 36,916 | 2.6 | 0.5 |
| Fellowships and traineeships | 8,160 | 7,967 | 7,845 | 7,928 | 8,122 | 8,343 | 8,606 | 3.2 | 0.9 |
| Research assistantships | 9,545 | 9,801 | 9,774 | 9,986 | 10,820 | 11,189 | 12,059 | 7.8 | 4.0 |
| Teaching assistantships | 9,120 | 9,037 | 9,155 | 8,956 | 8,914 | 8,936 | 8,609 | 3.7 | 1.0 |
| Other types of support | 2,177 | 2,120 | 2,130 | 2,264 | 2,112 | 2,010 | 2,126 | 2.7 | 0.3 |
| Self-support | 6,815 | 6,529 | 6,322 | 6,014 | 5,865 | 5,505 | 5,516 | 0.2 | 3.5 |
| Health sciences | 22,303 | 22,111 | 20,927 | 20,553 | 20,884 | 21,406 | 21,431 | 0.1 | 0.7 |
| Fellowships and traineeships | 8,034 | 7,691 | 6,704 | 6,033 | 6,034 | 6,505 | 6,318 | 2.9 | 3.9 |
| Research assistantships | 1,448 | 1,477 | 1,493 | 1,567 | 1,797 | 2,160 | 2,320 | 7.4 | 8.2 |
| Teaching assistantships | 1,960 | 1,949 | 2,071 | 2,077 | 2,210 | 2,188 | 2,288 | 4.6 | 2.6 |
| Other types of support | 2,376 | 2,107 | 1,734 | 2,111 | 2,233 | 2,129 | 2,097 | 4.4 | 1.8 |
| Self-support | 8,485 | 8,887 | 8,925 | 8,765 | 8,610 | 8,424 | 8,408 | 0.2 | 0.2 |
| Psychology | 21,580 | 21,544 | 21,103 | 21,309 | 21,578 | 21,524 | 22,007 | 2.2 | 0.3 |
| Fellowships and traineeships | 3,447 | 3,167 | 2,915 | 2,546 | 2,635 | 2,769 | 2,588 | 6.5 | 4.7 |
| Research assistantships | 2,342 | 2,664 | 2,510 | 2,657 | 2,762 | 2,867 | 2,889 | 0.8 | 3.6 |
| Teaching assistantships | 4,424 | 4,604 | 4,550 | 4,640 | 4,669 | 4,817 | 4,974 | 3.3 | 2.0 |
| Other types of support | 2,283 | 2,579 | 2,242 | 2,231 | 2,430 | 2,371 | 2,691 | 6.6 | 2.2 |
| Self-support | 9,084 | 8,530 | 8,886 | 9,235 | 9,082 | 8,700 | 8,865 | 1.9 | 0.4 |
| Social sciences | 51,518 | 51,402 | 49,211 | 48,080 | 47,186 | 47,085 | 47,589 | 1.1 | 1.3 |
| Fellowships and traineeships | 9,337 | 8,399 | 7,644 | 7,787 | 7,638 | 7,804 | 8,138 | 4.3 | 2.3 |
| Research assistantships | 5,316 | 5,237 | 4,977 | 5,164 | 5,298 | 5,227 | 5,341 | 2.2 | 0.1 |
| Teaching assistantships | 8,962 | 9,455 | 9,587 | 9,318 | 9,468 | 9,383 | 9,442 | 0.6 | 0.9 |
| Other types of support | 4,644 | 5,237 | 5,376 | 5,134 | 4,663 | 4,507 | 4,577 | 0.3 | 0.2 |
| Self-support | 23,259 | 23,074 | 21,627 | 20,677 | 20,119 | 20,164 | 20,091 | 0.4 | 2.4 |

SOURCE: National Science Foundation, *Academic Science/Engineering: Graduate Enrollment and Support, Fall 1986* (forthcoming)

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## Appendix table 2-14. Baccalaureate sources of 1984 S/E doctorate recipients, by institutional type

| Field | Total | Total Classified | Research institutions | Other doctorate-granting institutions | Comprehensive institutions | Liberal arts colleges | Specialized institutions |
|---|---|---|---|---|---|---|---|
| | | | Percent of classified institutions | | | | |
| Physical sciences | 3,212 | 3,212 | 31.3 | 27.1 | 25.1 | 14.2 | 2.3 |
| Physics and astronomy | 767 | 767 | 42.8 | 25.9 | 18.8 | 9.4 | 3.1 |
| Chemistry | 1,373 | 1,373 | 21.8 | 28.0 | 31.8 | 16.9 | 1.4 |
| Earth, atmospheric and marine sciences. | 486 | 486 | 34.8 | 27.4 | 19.8 | 14.8 | 3.3 |
| Mathematics and computer sciences | 586 | 586 | 35.5 | 26.3 | 22.0 | 13.8 | 2.4 |
| Life sciences | 4,670 | 4,661 | 34.3 | 31.0 | 21.4 | 11.8 | 1.5 |
| Biological sciences | 3,353 | 3,349 | 34.7 | 29.5 | 22.0 | 12.9 | 0.9 |
| Health sciences | 588 | 587 | 27.4 | 31.0 | 24.2 | 12.3 | 5.1 |
| Agricultural sciences | 729 | 725 | 38.2 | 37.9 | 16.3 | 6.2 | 1.4 |
| Social sciences | 4,866 | 4,860 | 28.2 | 29.8 | 26.2 | 15.2 | 0.7 |
| Psychology | 2,919 | 2,916 | 26.2 | 29.5 | 27.8 | 15.8 | 0.7 |
| Economics | 472 | 471 | 33.3 | 33.8 | 19.3 | 13.2 | 0.4 |
| Anthropology and sociology | 714 | 712 | 30.5 | 28.5 | 24.6 | 16.2 | 0.3 |
| Political sciences | 396.0 | 396.0 | 30.3 | 29.0 | 26.3 | 12.1 | 2.3 |
| Engineering | 1,394 | 1,394 | 47.7 | 31.0 | 12.3 | 3.9 | 5.0 |

SOURCE: National Research Council, *Doctorate Recipients from U.S. Universities. Summary Report 1984*, p.13

See figure 2-5.

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## Appendix table 2-15. Baccalaureate origins of Ph.D.'s for selected categories of undergraduate institutions: pre-1963, 1963-72, 1973-82

| Baccalaureate school[1] | Engineering | | | Physical sciences[2] | | | Environmental sciences[3] | | | Biological sciences | | | Social sciences | | | Non S/E fields | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-1963 | 1963-72 | 1973-82 | Pre-1963 | 1963-72 | 1973-82 | Pre-1963 | 1963-72 | 1973-82 | Pre-1963 | 1963-72 | 1973-82 | Pre-1963 | 1963-72 | 1973-82 | Pre-1963 | 1963-72 | 1973-82 |
| | Percent | | | | | | | | | | | | | | | | | |
| Schools granting doctorates 1981/1982: | | | | | | | | | | | | | | | | | | |
| Schools granting > 40 S/E Ph.D.'s (171)[1] | 68.4 | 60.0 | 44.3 | 56.9 | 49.3 | 43.4 | 63.1 | 57.2 | 53.0 | 59.8 | 47.2 | 48.4 | 22.3 | 49.6 | 47.6 | 47.3 | 42.0 | 39.2 |
| Schools granting 40 or fewer S/E Ph.D.'s (143) | 1.9 | 5.8 | 5.0 | 5.5 | 6.8 | 6.8 | 3.8 | 4.7 | 5.9 | 5.7 | 6.3 | 6.6 | 5.1 | 5.7 | 6.8 | 7.2 | 8.7 | 9.1 |
| Nondoctoral schools 1981/1982: | | | | | | | | | | | | | | | | | | |
| Schools granting up to Master's (1,096) | 7.5 | 8.3 | 7.6 | 27.7 | 26.8 | 25.0 | 16.6 | 19.8 | 22.1 | 19.8 | 24.6 | 25.0 | 26.7 | 30.7 | 30.8 | 35.7 | 38.3 | 38.7 |
| Schools granting Bachelor's (329) | 0.3 | 0.4 | 0.7 | 1.5 | 1.2 | 1.5 | 0.4 | 0.6 | 0.9 | 1.0 | 1.2 | 1.5 | 1.1 | 0.9 | 1.6 | 2.0 | 1.8 | 2.4 |
| Foreign schools (NA) | 18.9 | 24.8 | 39.3 | 7.7 | 14.7 | 21.3 | 15.4 | 16.8 | 16.4 | 12.2 | 18.3 | 15.7 | 8.4 | 12.0 | 10.7 | 5.7 | 7.4 | 8.2 |

[1]Number of institutions in each category in parentheses.
[2]Includes physics, mathematics, and chemistry.
[3]Includes astronomy, atmospheric, earth and ocean sciences.

Note: Data may not add to 100% because defunct and unknown institutions are omitted.

SOURCE: National Research Council and Lois Peters, unpublished tabulations.

## Appendix table 2-16. Type of baccalaureate institution of 1983-85 S/E doctorate recipients, by gender and race of recipients

| | All institutions | Type of baccalaureate institution[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | Unclassified & unknown | Non-U.S. institutions |
| All doctorates: | | | | | | | | |
| Number | 41,249 | 12,651 | 11,287 | 8,898 | 4,857 | 690 | 448 | 2,418 |
| Percent | 100 | 31 | 27 | 22 | 12 | 2 | 1 | 6 |
| Men: | | | | | | | | |
| Number | 29,267 | 9,153 | 8,160 | 6,270 | 2,875 | 610 | 323 | 1,875 |
| Percent | 100 | 31 | 28 | 21 | 10 | 2 | 1 | 6 |
| Women: | | | | | | | | |
| Number | 11,982 | 3,498 | 3,127 | 2,627 | 1,982 | 80 | 125 | 543 |
| Percent | 100 | 29 | 26 | 22 | 17 | 1 | 1 | 5 |
| Native American: | | | | | | | | |
| Number | 99 | 20 | 39 | 24 | 8 | 5 | 2 | 1 |
| Percent | 100 | 20 | 39 | 24 | 8 | 5 | 2 | 1 |
| Asian: | | | | | | | | |
| Number | 2,331 | 525 | 205 | 130 | 99 | 13 | 29 | 1,330 |
| Percent | 100 | 23 | 9 | 6 | 4 | 1 | 1 | 57 |
| Black: | | | | | | | | |
| Number | 972 | 196 | 190 | 358 | 162 | 10 | 8 | 48 |
| Percent | 100 | 20 | 20 | 37 | 17 | 1 | 1 | 5 |
| Hispanic: | | | | | | | | |
| Number | 831 | 182 | 158 | 309 | 59 | 11 | 25 | 87 |
| Percent | 100 | 22 | 19 | 37 | 7 | 1 | 3 | 10 |
| White: | | | | | | | | |
| Number | 35,885 | 11,352 | 10,429 | 7,872 | 4,397 | 628 | 319 | 888 |
| Percent | 100 | 32 | 29 | 22 | 12 | 2 | 1 | 2 |
| Other & unknown | | | | | | | | |
| Number | 1,131 | 376 | 266 | 205 | 132 | 23 | 65 | 64 |
| Percent | 100 | 33 | 24 | 18 | 12 | 2 | 6 | 6 |

[1]Modified Carnegie Commission classification. See notes on appendix table 2-17

SOURCE: National Science Foundation, Division of Science Resources Studies. *Baccalaureate Origins of Science and Engineering Doctorate Recipients* (forthcoming)

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## Appendix table 2-17. Baccalaureate origins: producers of baccalaureates receiving 1984 doctorates

| Top 30 producers in absolute numbers | | | Top 30 producers relative to total class of 1974 baccalaureates | | |
|---|---|---|---|---|---|
| Institution[1] | Number of baccalaureates | Institutional type[2] | Institution[1] | Number of baccalaureates | Institutional type[2] |
| University of California-Berkeley | 364 | I. Public | California Institute of Technology | 71/195 | I. Private |
| University of Michigan | 307 | I. Public | Harvey Mudd College/CA | 24/71 | IV. Private |
| University of Illinois | 267 | I. Public | Reed College/OR | 43/205 | IV. Private |
| University of California-Los Angeles | 253 | I. Public | University of Chicago/IL | 87/446 | I. Private |
| University of Wisconsin | 242 | I. Public | Swarthmore College/PA | 53/280 | IV. Private |
| Pennsylvania State University | 224 | I. Public | Massachusetts Institute of Technology | 200/1065 | I. Private |
| Cornell University | 217 | I. Private | Haverford College/PA | 27/162 | IV. Private |
| Ohio State University | 207 | I. Public | Oberlin College/OH | 95/623 | IV. Private |
| Michigan State University | 202 | I. Public | Kalamazoo College/MI | 32/218 | IV. Private |
| Massachusetts Institute of Technology | 200 | I. Private | Harvard University/MA | 157/1122 | I. Private |
| University of Texas-Austin | 197 | I. Public | Carleton College/MN | 46/333 | IV. Private |
| University of Maryland | 192 | I. Public | Brandeis University/MA | 73/531 | II. Private |
| University of Minnesota | 189 | I. Public | Princeton University/NJ | 127/936 | I. Private |
| University of Washington | 168 | I. Public | Cornell University/NY | 217/1616 | I. Private |
| Rutgers. The State University | 166 | II. Public | Pomona College/CA | 44/331 | IV. Private |
| Harvard University | 157 | I. Private | Barnard College/NY | 66/497 | IV. Private |
| Stanford University | 156 | I. Private | Bryn Mawr College/PA | 28/211 | IV. Private |
| Indiana University | 149 | II. Public | Wellesley College/MA | 60/467 | IV. Private |
| SUNY-Buffalo | 145 | II. Public | St Mary's Seminary & University/MD | 6/51 | IV. Private |
| University of Pennsylvania | 144 | I. Private | Wesleyan University/CT | 46/392 | IV. Private |
| CUNY-Brooklyn | 140 | III. Public | New College/FL | 17/147 | IV. Private |
| Purdue University | 138 | I. Public | Amherst College/MA | 35/309 | IV. Private |
| University of Massachusetts | 135 | II. Public | Brown University/RI | 111/1012 | II. Private |
| Brigham Young University | 132 | II. Private | Rice University/TX | 68/650 | II. Private |
| University of Missouri | 132 | I. Public | Point Loma College/CA | 13/126 | III. Private |
| University of California-Santa Barbara | 130 | II. Public | Yale University/CT | 124/1237 | I. Private |
| Princeton University | 127 | I. Private | Williams College/MA | 37/372 | IV. Private |
| University of Colorado | 125 | I. Public | University of Rochester/NY | 116/1171 | I. Private |
| University of Florida | 125 | I. Public | Grinnell College/IA | 30/303 | IV. Private |
| Yale University | 124 | I. Private | New England Conserv Music/MA | 5/52 | V. Private |

[1] Population limited to institutions granting 50 or more baccalaureate degrees in 1974.

[2] Carnegie classification: I – Research Institutions, II – Other Doctorate Institutions, III – Comprehensive Institutions, IV – Liberal Arts Colleges, V – Other Specialized Institutions

SOURCE: National Research Council *Doctorate Recipients from U.S. Universities, Summary Report 1984*, p 18

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## Appendix table 2-18. Leading baccalaureate sources of 1984 S/E Ph.D.'s, by productivity and by institutional type

| Institution[1] | Ratio of 1984 Ph.D.'s to 1974[2] baccalaureates | Type[3] |
|---|---|---|
| Physical sciences: | | |
| Harvey Mudd College/CA | 20/71 | IV, Private |
| California Institute of Technology | 41/195 | I, Private |
| Massachusetts Institute of Technology | 76/1065 | I, Private |
| Swarthmore College/PA | 16/280 | IV, Private |
| Reed College/OR | 10/205 | IV, Private |
| Carleton College/MN | 13/333 | IV, Private |
| University of Chicago/IL | 15/446 | I, Private |
| Washington College/MD | 5/149 | IV, Private |
| University of California-San Diego | 32/991 | I, Private |
| Colorado School of Mines | 8/255 | V, Public |
| Engineering: | | |
| California Institute of Technology | 23/195 | I, Private |
| Massachusetts Institute of Technology | 63/1065 | I, Private |
| Stevens Institute/NJ | 8/256 | V, Private |
| Harvey Mudd College/CA | 2/71 | IV, Private |
| Rensselaer Polytechnic Institute/NY | 21/805 | II, Private |
| Cornell University/NY | 31/1616 | I, Private |
| Carnegie-Mellon University/PA | 12/648 | II, Private |
| Worcester Polytechnic Institute/MA | 7/392 | V, Private |
| Clarkson College of Technology/NY | 10/572 | V, Private |
| Rice University/TX | 11/650 | II, Private |
| Life sciences: | | |
| Reed College/OR | 12/205 | IV, Private |
| University of Chicago/IL | 22/446 | I, Private |
| Cornell University/NY | 73/1616 | I, Private |
| Kalamazoo College/MI | 8/218 | IV, Private |
| California Institute of Technology | 7/195 | I, Private |
| Thomas Jefferson University/PA | 2/58 | V, Private |
| Brandeis University/MA | 18/531 | II, Private |
| Harvard University/MA | 37/1122 | I, Private |
| Massachusetts Institute of Technology | 34/1065 | I, Private |
| St. Johns College/MD | 2/63 | IV, Private |
| Social sciences: | | |
| St. Mary's Seminary and University/MD | 4/51 | IV, Private |
| University of Chicago/IL | 29/446 | I, Private |
| Swarthmore College/PA | 16/280 | IV, Private |
| Brandeis University/MA | 27/531 | II, Private |
| Barnard College-Columbia Univ/NY | 25/497 | IV, Private |
| Reed College/OR | 10/205 | IV, Private |
| New College/FL | 7/147 | IV, Private |
| Sarah Lawrence College/NY | 10/219 | IV, Private |
| Oberlin College/OH | 28/623 | IV, Private |
| Bryn Mawr College/PA | 9/211 | IV, Private |

[1] Named institutions refer to main campuses, unless otherwise noted. Some institution names have changed since 1974. Clarkson College of Technology is Clarkson University, New College has affiliated with the University of South Florida and is a public Other Doctorate-Granting Institutions.

[2] "Productivity" of 1984 Ph D.s in each field from schools that graduated 50 or more students in any category in 1974

[3] See appendix table 2-17 for type classification.

SOURCE. National Research Council, *Doctorate Recipients from U.S. Universities, Summary Report 1984,* p. 45

## Appendix table 2-19. Academic[1] doctoral scientists and engineers, by age and field: 1977, 1981, 1983, and 1985

| Fields | Years | Number | Age (years) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Under 30 | 30-39 | 40-49 | 50-59 | 60 + |
| | | | Percent | | | | |
| Total scientists and engineers | 1977 | 157,088 | 3.4 | 41.1 | 29.6 | 19.0 | 6.9 |
| | 1981 | 179,224 | 2.5 | 35.5 | 32.2 | 20.7 | 9.1 |
| | 1983 | 187,554 | 1.8 | 31.4 | 34.8 | 21.6 | 10.3 |
| | 1985 | 202.019 | 1.6 | 30.3 | 35.7 | 21.0 | 11.3 |
| Total scientists | 1977 | 141,373 | 3.5 | 41.6 | 28.9 | 18.8 | 7.1 |
| | 1981 | 161,247 | 2.6 | 36.4 | 31.6 | 20.1 | 9.3 |
| | 1983 | 167,305 | 1.8 | 32.0 | 34.4 | 21.3 | 10.4 |
| | 1985 | 180,505 | 1.5 | 30.7 | 36.0 | 20.4 | 11.3 |
| Physical scientists | 1977 | 25,556 | 4.2 | 41.4 | 30.7 | 16.8 | 6.9 |
| | 1981 | 26,786 | 3.4 | 30.5 | 34.5 | 20.6 | 11.0 |
| | 1983 | 26,453 | 2.5 | 24.4 | 38.8 | 22.6 | 11.8 |
| | 1985 | 28,206 | 2.2 | 25.3 | 37.2 | 22.7 | 12.6 |
| Mathematical scientists | 1977 | 11,781 | 4.5 | 48.6 | 27.9 | 13.2 | 5.7 |
| | 1981 | 12,274 | 3.1 | 35.0 | 38.3 | 16.6 | 7.0 |
| | 1983 | 12,770 | 2.2 | 28.2 | 42.3 | 19.1 | 8.2 |
| | 1985 | 13,027 | 2.8 | 25.4 | 40.1 | 22.2 | 9 5 |
| Computer specialists | 1977 | 2,118 | 4.6 | 52.2 | 27.9 | 13.4 | 1.9 |
| | 1981 | 2,954 | 3.0 | 45.4 | 31.6 | 15.5 | 4.3 |
| | 1983 | 3,905 | 2.1 | 45.8 | 32.0 | 13.1 | 6.9 |
| | 1985 | 5,124 | 1.9 | 38.8 | 40.3 | 12.9 | 6.0 |
| Environmental scientists | 1977 | 6,120 | 1.5 | 43.1 | 31.4 | 18.3 | 5.6 |
| | 1981 | 6,613 | 3.1 | 33.3 | 37.7 | 17.8 | 8.1 |
| | 1983 | 6,519 | 1.8 | 35.3 | 31.6 | 21.2 | 10.1 |
| | 1985 | 7,097 | 1.3 | 30.6 | 34.6 | 23.1 | 10.2 |
| Life scientists | 1977 | 45,643 | 3.5 | 41.7 | 27.8 | 19.6 | 7.3 |
| | 1981 | 54,437 | 2.9 | 39.5 | 29.5 | 19.7 | 8.4 |
| | 1983 | 57,315 | 1.9 | 34.9 | 32.8 | 20.7 | 9.6 |
| | 1985 | 61,788 | 1.4 | 34.0 | 34.5 | 19.9 | 10.2 |
| Psychologists | 1977 | 16,572 | 5.1 | 41.9 | 28.0 | 19.3 | 5.7 |
| | 1981 | 19,034 | 2.9 | 41.6 | 27.9 | 20.1 | 7.4 |
| | 1983 | 19,377 | 1.5 | 37.8 | 30.5 | 21.6 | 8.4 |
| | 1985 | 21,493 | 1.5 | 36.6 | 31.6 | 19.7 | 10.5 |
| Social scientists | 1977 | 33,583 | 2.2 | 38.1 | 29.5 | 21.2 | 8.9 |
| | 1981 | 39,149 | 1.3 | 33.8 | 31.2 | 22.2 | 11.5 |
| | 1983 | 40,966 | 1.1 | 29.5 | 34.1 | 22.5 | 12.7 |
| | 1985 | 43,770 | 0.9 | 27.2 | 38.1 | 20.1 | 13.7 |
| Total engineers | 1977 | 15,715 | 1.8 | 36.2 | 36.0 | 21.1 | 4.9 |
| | 1981 | 17,977 | 1.2 | 27.4 | 37.8 | 25.9 | 7.8 |
| | 1983 | 20,249 | 2.1 | 26.1 | 38.2 | 24.0 | 9.7 |
| | 1985 | 21,514 | 2.2 | 27.6 | 33.1 | 25.2 | 11.9 |

[1] Includes individuals employed in four-year colleges and universities only.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, Detailed Statistical Tables* (biennial series)

See figure 2-6.

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## Appendix table 2-20. Academic doctoral scientists and engineers, by primary work activity and field: 1981, 1983, and 1985

| Fields | Total | Research and development | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Basic Research | Applied Research | Development | Management of R&D | Teaching | Consulting | Other |
| | | | | | 1981 | | | | |
| Total scientists and engineers | 179,224 | 56,813 | 37,746 | 13,689 | 1,015 | 4,363 | 99,247 | 772 | 22,392 |
| Total scientists | 161.247 | 51.774 | 36,167 | 11.344 | 823 | 3,440 | 88,787 | 562 | 20,124 |
| Physical scientists | 26,786 | 10,532 | 7,795 | 1,650 | 259 | 828 | 14.118 | 53 | 2.083 |
| Mathematical scientists | 12,274 | 2,015 | 1,631 | 319 | 21 | 44 | 9,152 | 3 | 1,077 |
| Computer specialists | 2,954 | 901 | 389 | 181 | 253 | 78 | 1,469 | 63 | 521 |
| Environmental scientists | 6,613 | 2,754 | 1,660 | 642 | 76 | 376 | 3.436 | 0 | 423 |
| Life scientists | 54,437 | 27,002 | 20,156 | 5.509 | 123 | 1,214 | 20,400 | 151 | 6.884 |
| Psychologists | 19,034 | 3,519 | 2,095 | 1,116 | 26 | 282 | 11,620 | 119 | 3,776 |
| Social scientists | 39,149 | 5.051 | 2,441 | 1,927 | 65 | 618 | 28,592 | 146 | 5,360 |
| Total engineers | 17,977 | 5,039 | 1,579 | 2.345 | 192 | 923 | 10,460 | 210 | 2,268 |
| | | | | | 1983 | | | | |
| Total scientists and engineers | 187,554 | 57,557 | 39,443 | 13,584 | 1,509 | 3.021 | 100.452 | 684 | 28,861 |
| Total scientists | 167,305 | 51,667 | 37,210 | 11.138 | 970 | 2.349 | 89.233 | 618 | 25,787 |
| Physical scientists | 26,453 | 10.224 | 7,510 | 1,551 | 273 | 890 | 13,044 | 30 | 3,182 |
| Mathematical scientists | 12,770 | 2,108 | 1,659 | 348 | 44 | 57 | 9,214 | 79 | 1,369 |
| Computer specialists | 3.905 | 1,071 | 488 | 211 | 311 | 61 | 2,117 | 33 | 684 |
| Environmental scientists | 6,519 | 2.572 | 1,755 | 564 | 0 | 253 | 3.250 | 13 | 684 |
| Life scientists | 57,315 | 27,282 | 21,078 | 5.223 | 225 | 756 | 20,805 | 311 | 8,917 |
| Psychologists | 19,377 | 3.217 | 2.040 | 1,040 | 24 | 113 | 11,478 | 121 | 4,561 |
| Social scientists | 40,966 | 5,193 | 2,680 | 2.201 | 93 | 219 | 29,325 | 58 | 6,390 |
| Total engineers | 20.249 | 5.890 | 2,233 | 2.446 | 539 | 672 | 11,219 | 66 | 3,074 |
| | | | | | 1985 | | | | |
| Total scientists and engineers | 202.019 | 64.487 | 43,579 | 15,653 | 1,318 | 3,937 | 103,652 | 1,204 | 32,676 |
| Total scientists | 180,505 | 58.246 | 41,194 | 13,269 | 914 | 2.869 | 91,761 | 1,064 | 29,434 |
| Physical scientists | 28,206 | 11,570 | 8,703 | 1,745 | 247 | 875 | 13.545 | 14 | 3,077 |
| Mathematical scientists | 13.027 | 2.469 | 2.089 | 304 | 3 | 73 | 8,904 | 119 | 1,535 |
| Computer specialists | 5,124 | 1,481 | 744 | 337 | 311 | 89 | 2,629 | 68 | 946 |
| Environmental scientists | 7,097 | 3,051 | 1,940 | 721 | 40 | 350 | 3,231 | 23 | 792 |
| Life scientists | 61,788 | 30,113 | 22,749 | 6,104 | 252 | 1,008 | 20,676 | 342 | 10,657 |
| Psychologists | 21,493 | 3,681 | 2,074 | 1,447 | 35 | 125 | 11,953 | 325 | 5,534 |
| Social scientists | 43,770 | 5,881 | 2,895 | 2,611 | 26 | 349 | 30,823 | 173 | 6,893 |
| Total engineers | 21,514 | 6.241 | 2,385 | 2,384 | 404 | 1,068 | 11,891 | 140 | 3,242 |

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States Detailed Statistical Tables* (biennial series)

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## Appendix table 2-21. Academic doctoral scientists and engineers who teach, by field and rank: 1981, 1983, and 1985

| Field | Total | Professor | Associate Professor | Assistant Professor | Instructor | Other | No report |
|---|---|---|---|---|---|---|---|
| | | | | 1981 | | | |
| Total scientists and engineers | 130,597 | 57,295 | 38,257 | 28,714 | 1,237 | 4,133 | 326 |
| Total scientists | 117,417 | 50,089 | 34,577 | 26,774 | 1,237 | 3,831 | 326 |
| Physical scientists | 18,423 | 9,938 | 4,745 | 2,701 | 134 | 686 | 61 |
| Mathematical scientists | 10,804 | 4,924 | 3,377 | 2,125 | 160 | 177 | 25 |
| Computer specialists | 1,950 | 579 | 717 | 549 | 30 | 54 | 0 |
| Environmental scientists | 4,416 | 1,972 | 1,319 | 1,034 | 6 | 79 | 0 |
| Life scientists | 33,893 | 13,278 | 10,248 | 8,140 | 535 | 1,528 | 89 |
| Psychologists | 14,902 | 5,779 | 4,346 | 3,876 | 101 | 584 | 100 |
| Social scientists | 33,029 | 13,619 | 9,825 | 8,349 | 271 | 723 | 51 |
| Total engineers | 13,180 | 7,206 | 3,680 | 1,940 | 0 | 302 | 0 |
| | | | | 1983 | | | |
| Total scientists and engineers | 135,990 | 62,358 | 40,789 | 26,529 | 745 | 4,171 | 1,398 |
| Total scientists | 121,088 | 54,311 | 36,557 | 24,267 | 743 | 3,918 | 1,292 |
| Physical scientists | 17,656 | 10,546 | 4,074 | 2,281 | 102 | 521 | 132 |
| Mathematical scientists | 11,289 | 5,295 | 3,523 | 2,148 | 115 | 132 | 76 |
| Computer specialists | 2,559 | 842 | 898 | 688 | 5 | 117 | 9 |
| Environmental scientists | 4,505 | 2,073 | 1,291 | 957 | 4 | 129 | 51 |
| Life scientists | 35,415 | 14,911 | 10,693 | 7,497 | 258 | 1,669 | 387 |
| Psychologists | 14,956 | 6,157 | 4,822 | 3,195 | 110 | 429 | 243 |
| Social scientists | 34,708 | 14,487 | 11,256 | 7,501 | 149 | 921 | 394 |
| Total engineers | 14,902 | 8,047 | 4,232 | 2,262 | 2 | 253 | 106 |
| | | | | 1985 | | | |
| Total scientists and engineers | 143,360 | 64,103 | 41,265 | 29,110 | 1,453 | 6,550 | 879 |
| Total scientists | 127,583 | 56,228 | 37,181 | 25,965 | 1,451 | 6,005 | 753 |
| Physical scientists | 18,749 | 10,677 | 4,100 | 2,669 | 229 | 947 | 127 |
| Mathematical scientists | 11,567 | 5,702 | 3,136 | 2,292 | 142 | 230 | 65 |
| Computer specialists | 3,619 | 1,009 | 1,276 | 1,039 | 46 | 247 | 2 |
| Environmental scientists | 4,550 | 2,251 | 1,227 | 915 | 26 | 117 | 14 |
| Life scientists | 35,956 | 14,683 | 11,038 | 7,437 | 423 | 2,197 | 178 |
| Psychologists | 16,029 | 6,649 | 4,826 | 3,328 | 252 | 822 | 152 |
| Social scientists | 37,113 | 15,257 | 11,578 | 8,285 | 333 | 1,445 | 215 |
| Total engineers | 15,777 | 7,875 | 4,084 | 3,145 | 2 | 545 | 126 |

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, Detailed Statistical Tables* (biennial series)

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## Appendix table 2-22. Full-time S/E graduate students in doctorate-granting institutions, by gender, support, and field: 1986

| | Engineering | | Physical sciences | | Environmental sciences | | Mathematical sciences | | Computer sciences | | Life sciences | | Psychology | | Social sciences | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Enrollment | 52.760 | 7.165 | 21,539 | 5.535 | 8.091 | 2.818 | 8.599 | 3.168 | 10.610 | 2.894 | 34.680 | 32.525 | 8.890 | 13.117 | 26.627 | 20,962 |
| Support: | | | | | | | | | | | | | | | | |
| Federal | 11,043 | 1.322 | 7,714 | 1,720 | 2.277 | 738 | 808 | 184 | 1,588 | 230 | 9,187 | 9,418 | 792 | 1.101 | 1,769 | 1,476 |
| DOD | 3.783 | 310 | 966 | 176 | 383 | 70 | 363 | 66 | 898 | 116 | 264 | 167 | 73 | 59 | 124 | 26 |
| HHS | 448 | 142 | 1,442 | 550 | 18 | 20 | 13 | 11 | 40 | 5 | 5.669 | 6.774 | 376 | 568 | 153 | 390 |
| NIH | 366 | 118 | 1,310 | 517 | 13 | 11 | 11 | 8 | 39 | 4 | 5.115 | 3.746 | 237 | 348 | 86 | 191 |
| Other HHS | 82 | 24 | 132 | 33 | 5 | 9 | 2 | 3 | 1 | 1 | 554 | 3.028 | 139 | 220 | 67 | 199 |
| NSF | 2.744 | 367 | 3.063 | 598 | 1.010 | 340 | 289 | 68 | 452 | 75 | 716 | 483 | 96 | 135 | 228 | 140 |
| Other federal | 4.068 | 503 | 2.243 | 396 | 866 | 308 | 143 | 39 | 198 | 34 | 2.538 | 1.994 | 247 | 339 | 1,264 | 920 |
| Institutional support | 17,440 | 2.537 | 10,917 | 3.101 | 2,972 | 1.194 | 5.911 | 2,271 | 3.368 | 947 | 14.575 | 11.696 | 3,944 | 5.978 | 11.950 | 8,678 |
| Other outside support | 9,131 | 1,068 | 1,518 | 389 | 995 | 232 | 484 | 103 | 1,160 | 264 | 4,195 | 2.227 | 573 | 754 | 2.482 | 1,143 |
| Other U.S | 7,127 | 957 | 1,234 | 332 | 716 | 197 | 197 | 48 | 926 | 225 | 2.389 | 1.716 | 539 | 727 | 1,113 | 790 |
| Foreign | 2,004 | 111 | 284 | 57 | 279 | 35 | 287 | 55 | 234 | 39 | 1.806 | 511 | 34 | 27 | 1.369 | 353 |
| Self-support | 15,146 | 2,238 | 1,390 | 325 | 1,847 | 654 | 1,396 | 610 | 4,494 | 1,453 | 6.723 | 9.184 | 3,581 | 5,284 | 10,426 | 9,665 |
| | Percent | | | | | | | | | | | | | | | |
| Enrollment | 88.0 | 12.0 | 79.6 | 20 4 | 74.2 | 25.8 | 73.1 | 26.9 | 78.6 | 21.4 | 51.6 | 48.4 | 40.4 | 59.6 | 56.0 | 44.0 |
| Support: | | | | | | | | | | | | | | | | |
| Federal | 89.3 | 10.7 | 81.8 | 18.2 | 75.5 | 24.5 | 81.5 | 18.5 | 87.3 | 12.7 | 49.4 | 50.6 | 41.8 | 58.2 | 54.5 | 45.5 |
| DOD | 92.4 | 7.6 | 84.6 | 15.4 | 84.5 | 15.5 | 84.6 | 15.4 | 88.6 | 11.4 | 61.3 | 38.7 | 55.3 | 44.7 | 82.7 | 17.3 |
| HHS | 75.9 | 24.1 | 72.4 | 27.6 | 47.4 | 52.6 | 54.2 | 45.8 | 88.9 | 11.1 | 45.6 | 54.4 | 39.8 | 60.2 | 28.2 | 71.8 |
| NIH | 75.6 | 24.4 | 71.7 | 28.3 | 54.2 | 45.8 | 57.9 | 42.1 | 90.7 | 9.3 | 57.7 | 42.3 | 40.5 | 59.5 | 31.0 | 69.0 |
| Other HHS | 77.4 | 22.6 | 80.0 | 20.0 | 35.7 | 64.3 | 40.0 | 60.0 | 50.0 | 50.0 | 15.5 | 84.5 | 38.7 | 61.3 | 25.2 | 74.8 |
| NSF | 88.2 | 11.8 | 83.7 | 16.3 | 74.8 | 25.2 | 81.0 | 19.0 | 85.8 | 14.2 | 59.7 | 40 3 | 41.6 | 58.4 | 62.0 | 38.0 |
| Other federal | 89.0 | 11.0 | 85.0 | 15.0 | 73.8 | 26.2 | 78.6 | 21.4 | 85.3 | 14.7 | 56.0 | 44.0 | 42.2 | 57.8 | 57.9 | 42.1 |
| Institutional support | 87.3 | 12.7 | 77.9 | 22.1 | 71.3 | 28.7 | 72.2 | 27.8 | 78.1 | 21.9 | 55.5 | 44.5 | 39.8 | 60.2 | 57.9 | 42.1 |
| Other outside support | 89.5 | 10.5 | 79.6 | 20.4 | 81.1 | 18.9 | 82.5 | 17.5 | 81.5 | 18.5 | 65.3 | 34.7 | 43.2 | 56.8 | 68.5 | 31.5 |
| Other U.S | 88.2 | 11.8 | 78.8 | 21.2 | 78.4 | 21.6 | 80.4 | 19.6 | 80.5 | 19.5 | 58.2 | 41.8 | 42.6 | 57.4 | 58.5 | 41.5 |
| Foreign | 94.8 | 5.2 | 83.3 | 16.7 | 88.9 | 11.1 | 83.9 | 16.1 | 85.7 | 14.3 | 77.9 | 22.1 | 55.7 | 44.3 | 79.5 | 20.5 |
| Self-support | 87.1 | 12.9 | 81.0 | 19.0 | 73.9 | 26.1 | 69.6 | 30.4 | 75.6 | 24.4 | 42.3 | 57.7 | 40.4 | 59.6 | 51.9 | 48.1 |

SOURCE. National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support, Fall 1986* (forthcoming)

Science & Engineering Indicators—1987

## Appendix table 3-1. Employment status of scientists and engineers, by field and gender: 1976, 1980, 1986

| Field and gender | Total Employed | | | Employed in S/E | | |
|---|---|---|---|---|---|---|
| | 1976 | 1980 | 1986 | 1976 | 1980 | 1986 |
| Total, all S/E fields | 2,331,200 | 2,860,400 | 4,626,500 | 2,122,100 | 2,542,700 | 3,919,900 |
| Men | 2,131,600 | 2,544,800 | 3,927,800 | 1,947,200 | 2,269,900 | 3,393,700 |
| Women | 199,700 | 315,600 | 698,600 | 174,900 | 272,800 | 526,700 |
| Total scientists | 959,500 | 1,184,500 | 2,186,300 | 843,800 | 1,032,800 | 1,676,400 |
| Men | 781,300 | 918,000 | 1,586,700 | 689,100 | 806,200 | 1,242,800 |
| Women | 178,200 | 266,500 | 599,600 | 154,700 | 226,600 | 433,600 |
| Physical scientists | 188,900 | 215,200 | 288,400 | 154,900 | 166,300 | 264,900 |
| Men | 172,700 | 194,500 | 250,100 | 143,600 | [illegible] | 229,500 |
| Women | 16,200 | 20,800 | 38,300 | 11,300 | 14,500 | 35,400 |
| Mathematical scientists | 48,600 | 64,300 | 131,000 | 43,800 | 57,300 | 103,900 |
| Men | 37,100 | 46,400 | 97,100 | 33,700 | 42,100 | 78,900 |
| Women | 11,500 | 13,000 | 33,900 | 10,000 | 15,200 | 25,000 |
| Computer specialists | 119,000 | 207,800 | 562,600 | 116,000 | 196,700 | 437,200 |
| Men | 98,400 | 149,900 | 400,000 | 95,100 | 147,600 | 308,700 |
| Women | 20,600 | 57,900 | 162,500 | 20,900 | 49,100 | 128,400 |
| Environmental scientists | 54,800 | 77,600 | 111,300 | 46,600 | 63,100 | 97,300 |
| Men | 50,900 | 66,800 | 98,400 | 44,000 | 54,700 | 87,200 |
| Women | 3,900 | 10,700 | 12,900 | 2,600 | 8,400 | 10,100 |
| Life scientists | 213,500 | 287,500 | 411,800 | 198,200 | 267,300 | 340,500 |
| Men | 179,600 | 234,400 | 309,000 | 167,700 | 218,400 | 257,100 |
| Women | 33,900 | 53,100 | 102,800 | 30,500 | 48,900 | 83,300 |
| Psychologists | 112,500 | 128,100 | 253,500 | 103,700 | 112,500 | 172,800 |
| Men | 76,900 | 79,400 | 138,400 | 71,600 | 70,400 | 99,500 |
| Women | 35,600 | 48,700 | 115,200 | 32,000 | 42,100 | 73,300 |
| Social scientists | 222,300 | 204,000 | 427,800 | 180,500 | 169,700 | 259,800 |
| Men | 165,700 | 146,700 | 293,800 | 133,200 | 121,300 | 181,800 |
| Women | 56,600 | 57,200 | 134,000 | 47,300 | 48,300 | 78,000 |
| Total engineers | 1,371,700 | 1,675,900 | 2,440,100 | 1,278,300 | 1,509,900 | 2,243,500 |
| Men | 1,350,300 | 1,626,700 | 2,341,100 | 1,258,100 | 1,463,600 | 2,150,900 |
| Women | 21,400 | 49,200 | 99,000 | 20,200 | 46,200 | 92,600 |
| Aeronautical/astronautical | 56,800 | 69,500 | 110,500 | 55,700 | 65,000 | 104,200 |
| Men | 56,400 | 68,300 | 106,200 | 55,100 | 63,700 | 100,300 |
| Women | 400 | 1,200 | 4,300 | 600 | 1,300 | 3,900 |
| Chemical | 77,500 | 94,500 | 149,000 | 76,400 | 89,000 | 131,500 |
| Men | 75,000 | 90,000 | 137,800 | 73,700 | 84,500 | 121,200 |
| Women | 2,500 | 4,500 | 11,200 | 2,800 | 4,500 | 10,300 |
| Civil | 188,200 | 232,100 | 346,300 | 182,800 | 217,000 | 319,100 |
| Men | 182,800 | 226,300 | 333,400 | 178,100 | 211,500 | 307,200 |
| Women | 5,400 | 5,800 | 12,900 | 4,800 | 5,500 | 11,900 |
| Electrical/electronics | 283,000 | 383,100 | 574,500 | 267,900 | 357,400 | 540,800 |
| Men | 281,400 | 357,400 | 555,500 | 266,500 | 350,200 | 523,200 |
| Women | 1,600 | 7,600 | 18,900 | 1,400 | 7,200 | 17,600 |
| Mechanical | 276,200 | 322,600 | 492,600 | 272,800 | 308,800 | 453,700 |
| Men | 273,900 | 316,000 | 478,600 | 270,600 | 302,000 | 440,100 |
| Women | 2,300 | 6,600 | 14,000 | 2,200 | 6,800 | 13,600 |
| Other engineers | 490,000 | 574,100 | 767,300 | 422,700 | 472,600 | 694,200 |
| Men | 480,900 | 550,600 | 729,600 | 414,200 | 451,600 | 658,900 |
| Women | 9,100 | 23,500 | 37,700 | 8,500 | 21,000 | 35,300 |

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures O-10, O-11, O-12, O-13 in Overview and figures 3-1 and 3-18

**Appendix table 3-2. Scientists and engineers as a percent of total U.S. workforce: 1976-86**

| Year | (Percent) |
|---|---|
| 1976 | 2.4 |
| 1978 | 2.5 |
| 1980 | 2.6 |
| 1982 | 2.9 |
| 1984 | 3.3 |
| 1986 | 3.6 |

SOURCES: National Science Foundation. *U.S. Scientists and Engineers: 1986* (forthcoming) *Economic Report of the President. 1987.* p 282

See figure 3-1. Science & Engineering Indicators—1987

**Appendix table 3-3. Average annual percent increases in employment in science and engineering, and other economic variables: 1976-86**

| | 1976-80 | 1980-86 | 1976-86 |
|---|---|---|---|
| | | Percent | |
| Scientists and engineers | 4.6 | 7.9 | 6.6 |
| Scientists | 5.2 | 7.8 | 6.7 |
| Engineers | 4.3 | 7.9 | 6.4 |
| U.S. employment | 2.8 | 1.7 | 2.1 |
| Real[1] gross national product | 3.0 | 2.4 | 2.6 |

[1] Gross national product measured in constant dollars. using the GNP deflator.

SOURCES: National Science Foundation. *U.S. Scientists and Engineers. 1986* (forthcoming): *Economic Report of the President. 1987,* pp. 246. 282

See figure O-9 in Overview. Science & Engineering Indicators—1987

## Appendix table 3-4. Scientists and engineers, by field and primary work activity: 1976, 1986

| Field | Total | | Primary work activity: Research | | Development | | Management of R&D | | Management—other than R&D | | Teaching | | Production inspection | | Statistical work/computing | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 |
| Total, all S/E fields | 2,122,100 | 3,919,900 | 209,000 | 376,000 | 430,200 | 846,900 | 212,700 | 371,700 | 386,600 | 628,400 | 152,200 | 336,600 | 223,200 | 512,800 | 101,100 | 384,500 |
| Total scientists | 843,700 | 1,676,400 | 159,100 | 277,400 | 61,400 | 166,100 | 83,700 | 144,400 | 105,100 | 209,600 | 131,500 | 283,400 | 29,000 | 114,300 | 66,600 | 275,500 |
| Physical scientists | 154,900 | 264,900 | 48,900 | 68,900 | 21,300 | 43,600 | 26,800 | 42,300 | 13,400 | 19,300 | 16,200 | 44,200 | 1,600 | 29,600 | 3,100 | 6,500 |
| Mathematical scientists | 43,800 | 103,900 | 6,000 | 11,600 | 2,400 | 5,600 | 6,500 | 13,800 | 5,900 | 9,400 | 15,800 | 43,200 | 1,200 | 2,600 | 3,900 | 14,300 |
| Computer specialists | 116,000 | 437,200 | 1,800 | 13,800 | 25,400 | 87,300 | 8,400 | 27,200 | 15,600 | 35,500 | 3,500 | 16,300 | 3,700 | 15,400 | 36,200 | 206,000 |
| Environmental scientists | 46,600 | 97,300 | 17,100 | 28,900 | 3,400 | 6,200 | 5,900 | 7,300 | 6,000 | 11,300 | 2,400 | 8,200 | 2,600 | 20,600 | 2,000 | 6,300 |
| Life scientists | 198,200 | 340,500 | 55,600 | 108,100 | 6,700 | 14,600 | 18,400 | 28,700 | 38,400 | 51,900 | 28,100 | 58,700 | 14,000 | 35,600 | 3,200 | 9,100 |
| Psychologists | 103,700 | 172,800 | 6,700 | 15,300 | 1,200 | 2,300 | 4,200 | 7,100 | 12,300 | 25,500 | 20,900 | 38,200 | 1,800 | 2,600 | 1,100 | 2,800 |
| Social scientists | 180,500 | 269,800 | 23,000 | 30,800 | 1,000 | 6,400 | 13,500 | 17,900 | 13,500 | 56,900 | 44,600 | 74,600 | 4,100 | 7,900 | 15,100 | 30,500 |
| Total engineers | 1,278,300 | 2,243,500 | 49,800 | 98,700 | 368,900 | 680,800 | 128,900 | 227,300 | 256,500 | 418,700 | 20,700 | 53,100 | 179,800 | 398,500 | 34,600 | 108,900 |
| Aeronautical/astronautical | 55,700 | 104,200 | 5,500 | 9,600 | 20,100 | 39,700 | 13,800 | 20,600 | 4,900 | 9,400 | 1,000 | 2,400 | 4,400 | 10,800 | 1,800 | 5,700 |
| Chemical | 76,400 | 131,500 | 4,400 | 8,200 | 24,600 | 42,500 | 8,600 | 18,400 | 19,300 | 24,400 | 500 | 2,800 | 9,900 | 20,500 | 1,300 | 4,700 |
| Civil | 182,800 | 319,100 | 2,900 | 7,300 | 30,000 | 43,700 | 6,000 | 10,300 | 57,400 | 103,400 | 2,200 | 6,000 | 37,500 | 69,500 | 5,800 | 14,000 |
| Electrical/electronics | 267,900 | 540,800 | 11,800 | 27,300 | 101,400 | 209,700 | 38,300 | 76,900 | 40,100 | 74,600 | 4,400 | 12,700 | 27,400 | 81,100 | 6,300 | 22,700 |
| Mechanical | 272,800 | 453,700 | 8,400 | 16,800 | 106,700 | 187,300 | 28,700 | 48,500 | 56,300 | 79,800 | 5,300 | 8,900 | 29,700 | 67,200 | 3,100 | 11,800 |
| Other engineers | 422,700 | 694,200 | 16,800 | 29,500 | 86,100 | 157,900 | 33,500 | 52,600 | 78,500 | 127,100 | 7,300 | 20,300 | 70,900 | 149,400 | 16,300 | 50,000 |

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure 3-2.

Appendix table 3-5. Scientists and engineers, by field and type of employer: 1976, 1986

| Field | Total | | Type of employer | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Business/Industry | | Educational Institutions | | Federal Government | |
| | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 | 1976 | 1986 |
| Total, all S/E fields | 2,122,100 | 3,919,900 | 1,312,500 | 2,589,300 | 267,800 | 572,700 | 211,100 | 334,200 |
| Total scientists | 843,700 | 1,676,400 | 357,900 | 797,900 | 230,200 | 481,800 | 105,200 | 153,500 |
| Physical scientists | 154,900 | 264,900 | 86,800 | 146,700 | 30,600 | 68,700 | 20,500 | 28,600 |
| Mathematical scientists | 43,800 | 103,900 | 12,100 | 35,600 | 19,500 | 52,800 | 9,300 | 10,700 |
| Computer specialists | 116,000 | 437,200 | 85,800 | 341,300 | 6,000 | 32,500 | 8,700 | 32,100 |
| Environmental scientists | 46,600 | 97,300 | 25,800 | 55,500 | 5,000 | 16,500 | 9,300 | 16,800 |
| Life scientists | 198,200 | 340,500 | 64,100 | 102,800 | 59,600 | 136,600 | 37,300 | 40,200 |
| Psychologists | 103,700 | 172,800 | 21,000 | 39,700 | 41,700 | 72,800 | 5,000 | 5,400 |
| Social scientists | 180,500 | 269,800 | 62,300 | 76,200 | 67,800 | 102,000 | 15,100 | 19,700 |
| Total engineers | 1,278,300 | 2,243,500 | 954,600 | 1,791,400 | 37,700 | 90,900 | 105,900 | 180,700 |
| Aeronautical/astronautical | 55,700 | 104,200 | 39,900 | 77,400 | 1,800 | 3,600 | 11,100 | 17,500 |
| Chemical | 76,400 | 131,500 | 68,400 | 114,200 | 900 | 5,400 | 2,600 | 6,600 |
| Civil | 182,800 | 319,100 | 85,100 | 195,700 | 5,300 | 8,800 | 21,500 | 31,600 |
| Electrical/electronics | 267,900 | 540,800 | 210,600 | 439,800 | 10,400 | 24,600 | 27,600 | 52,700 |
| Mechanical | 272,800 | 453,700 | 227,900 | 394,500 | 8,500 | 17,000 | 15,300 | 28,700 |
| Other engineers | 422,700 | 694,200 | 322,700 | 569,800 | 10,800 | 31,500 | 27,800 | 43,600 |

SOUFCE: National Science Foundation. *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures 3-3, 3-4, 3-6, 3-7, and 3-11.

Science & Engineering Indicators—1987

## Appendix table 3-6. Employed doctoral scientists and engineers, by field, gender, and type of employer: 1973, 1985

| Field and gender | Total 1973 | Total 1985 | Business/Industry 1973 | Business/Industry 1985 | Educational Institutions 1973 | Educational Institutions 1985 | Federal Government 1973 | Federal Government 1985 |
|---|---|---|---|---|---|---|---|---|
| Total, all S/E fields | 220,300 | 400,400 | 53,400 | 125,800 | 129,300 | 211,600 | 18,200 | 26,300 |
| Men | 203,400 | 341,900 | 52,000 | 112,855 | 103,300 | 177,300 | 17,200 | 23,600 |
| Women | 16,900 | 58,500 | 1,400 | 12,945 | 12,100 | 34,300 | 1,000 | 2,700 |
| Total scientists | 184,600 | 334,500 | 35,600 | 87,900 | 116,300 | 189,900 | 15,500 | 22,500 |
| Men | 167,800 | 277,500 | 34,300 | 75,785 | 104,300 | 156,000 | 14,500 | 19,900 |
| Women | 16,800 | 57,000 | 1,300 | 12,115 | 12,100 | 33,900 | 1,000 | 2,600 |
| Physical scientists | 48,500 | 67,500 | 19,700 | 30,300 | 22,000 | 29,700 | 4,100 | 4,000 |
| Men | 46,600 | 62,800 | 19,300 | 28,600 | 20,700 | 27,400 | 4,000 | 3,700 |
| Women | 1,900 | 4,700 | 300 | 1,700 | 1,300 | 2,300 | 100 | 300 |
| Mathematical scientists | 12,100 | 16,800 | 900 | 1,900 | 10,500 | 13,600 | 500 | 900 |
| Men | 11,400 | 15,200 | 800 | 1,700 | 9,800 | 12,400 | 500 | 800 |
| Women | 800 | 1,600 | (1) | 200 | 700 | 1,200 | (1) | 100 |
| Computer specialists | 2,700 | 15,000 | 1,000 | 8,400 | 1,400 | 5,300 | 100 | 700 |
| Men | 2,600 | 13,400 | 1,000 | 7,400 | 1,300 | 4,800 | 100 | 701 |
| Women | 100 | 1,600 | (1) | 1,000 | (1) | 500 | (1) | (1) |
| Environmental scientists | 10,300 | 17,200 | 2,200 | 5,300 | 5,200 | 7,200 | 2,000 | 3,300 |
| Men | 10,100 | 16,100 | 2,200 | 5,000 | 5,000 | (6,200) | 1,900 | 3,100 |
| Women | 300 | 1,100 | (1) | 300 | 200 | 13,400 | (1) | 200 |
| Life scientists | 56,700 | 101,800 | 7,100 | 19,200 | 38,200 | 61,800 | 5,800 | 8,000 |
| Men | 50,600 | 81,800 | 6,800 | 16,600 | 33,700 | 54,300 | 5,400 | 6,900 |
| Women | 6,100 | 20,000 | 300 | 2,600 | 4,600 | 7,500 | 500 | 1,100 |
| Psychologists | 24,800 | 52,100 | 3,100 | 15,500 | 15,000 | 24,500 | 1,200 | 1,000 |
| Men | 20,000 | 35,100 | 2,600 | 10,400 | 12,200 | 19,400 | 1,000 | 800 |
| Women | 4,800 | 17,000 | 500 | 5,100 | 2,900 | 5,100 | 200 | 200 |
| Social scientists | 29,400 | 64,000 | 1,700 | 7,400 | 24,000 | 43,800 | 1,700 | 4,600 |
| Men | 26,500 | 52,200 | 1,600 | 6,200 | 21,600 | 35,500 | 1,600 | 3,900 |
| Women | 2,900 | 11,800 | 100 | 1,200 | 2,400 | 8,300 | 100 | 700 |
| Total engineers | 35,800 | 65,900 | 17,800 | 37,900 | 13,000 | 21,700 | 2,700 | 3,800 |
| Men | 35,600 | 64,400 | 17,700 | 37,100 | 13,000 | 21,200 | 2,700 | 3,700 |
| Women | 100 | 1,500 | 100 | 800 | 100 | 500 | (1) | 100 |
| Aeronautical/astronautical | 1,700 | 3,800 | 600 | 2,100 | 400 | 700 | 300 | 600 |
| Men | 1,700 | 3,700 | 600 | 2,000 | 400 | 701 | 300 | 601 |
| Women | (1) | 100 | (1) | 100 | (1) | (1) | (1) | (1) |
| Chemical | 4,500 | 7,100 | 3,200 | 5,100 | 1,000 | 1,800 | 100 | 200 |
| Men | 4,500 | 7,000 | 3,200 | 5,000 | 1,000 | [illegible] | 100 | 201 |
| Women | (1) | 100 | (1) | 100 | (1) | (1) | (1) | (1) |
| Civil | 3,100 | 6,400 | 900 | 2,400 | 1,700 | 3,400 | 200 | 300 |
| Men | 3,100 | 6,300 | 900 | 2,401 | 1,700 | 3,401 | 200 | 301 |
| Women | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) |
| Electrical/electronics | 7,100 | 14,200 | 3,400 | [illegible] | 2,800 | 4,700 | 500 | 800 |
| Men | 7,100 | 13,900 | 3,400 | 6,400 | 2,800 | 4,600 | 500 | 801 |
| Women | (1) | 300 | (1) | 200 | (1) | 100 | (1) | (1) |
| Materials | 4,500 | 7,300 | 2,700 | 4,800 | 1,200 | 1,800 | 400 | 400 |
| Men | 4,400 | 7,100 | 2,700 | 4,600 | 1,200 | 1,801 | 300 | 401 |
| Women | (1) | 200 | (1) | 200 | (1) | (1) | (1) | (1) |
| Mechanical | 3,300 | 6,600 | 1,400 | 3,100 | 1,600 | 9,000 | 200 | 300 |
| Men | 3,300 | 6,500 | 1,400 | 3,101 | 1,600 | 9,001 | 200 | 301 |
| Women | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) |
| Nuclear | 1,300 | 2,400 | 700 | 1,500 | 300 | 500 | 200 | 100 |
| Men | 1,300 | 2,401 | 700 | 1,501 | 300 | 501 | 200 | [illegible] |
| Women | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Systems design | 2,000 | 3,700 | 1,000 | 2,500 | 600 | 800 | 200 | 100 |
| Men | 1,900 | 3,500 | 1,000 | 2,400 | 600 | 801 | 200 | 101 |
| Women | (1) | 200 | (1) | 100 | (1) | (1) | (1) | (1) |
| Other engineers | 8,600 | 14,300 | 3,900 | 7,800 | 3,300 | 5,000 | 800 | 1,000 |
| Men | 8,500 | 10,800 | 3,900 | 7,600 | 3,300 | 4,900 | 800 | 1,001 |
| Women | (1) | 10,800 | (1) | 200 | (1) | 100 | (1) | (1) |

[1] Too few cases to estimate

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 3-5.

Science & Engineering Indicators—1987

## Appendix table 3-7. Proportion of scientists and engineers employed in industry by sector and field: 1977, 1986

| Field | Nonmanufacturing 1977 | Nonmanufacturing 1986 | Manufacturing 1977 | Manufacturing 1986 |
|---|---|---|---|---|
| | Percent | | | |
| All S/E's | 43.3 | 44.9 | 56.7 | 55.1 |
| All Scientists | 56.5 | 66.3 | 43.5 | 33.7 |
| Computer specialists | 68.9 | 71.2 | 31.1 | 28.8 |
| Life scientists | 20.2 | 40.7 | 79.8 | 59.3 |
| Mathematical scientists | 70.0 | 76.6 | 30.0 | 23.4 |
| Physical scientists | 32.8 | 45.7 | 67.2 | 54.3 |
| Social scientists | 95.8 | 97.5 | 4.2 | 2.5 |
| All Engineers | 38.9 | 36.8 | 61.1 | 63.2 |
| Aeronautical/astronautical | 13.5 | 9.9 | 86.5 | 90.1 |
| Chemical | 28.3 | 23.3 | 71.7 | 76.8 |
| Civil | 91.6 | 91.0 | 8.4 | 9.0 |
| Electrical/electronics | 41.6 | 34.1 | 58.4 | 65.9 |
| Industrial | 13.4 | 11.1 | 86.6 | 88.9 |
| Mechanical | 37.2 | 30.0 | 62.8 | 70.0 |
| Other | 35.7 | 40.8 | 64.4 | 59.2 |

SOURCE: National Science Foundation, Division of Science Resources Studies, Employment Studies Group

See figures 3-8 and 3-9. Science & Engineering Indicators—1987

## Appendix table 3-8. Technicians employed in industry by field and sector: 1977, 1986

| Field | Total 1977 | Total 1986 | Non-manufacturing 1977 | Non-manufacturing 1986 | Manufacturing 1977 | Manufacturing 1986 |
|---|---|---|---|---|---|---|
| | Thousands | | | | | |
| All Technicians | 929.4 | 1550.1 | 474.5 | 954.3 | 454.9 | 595.8 |
| Computer Programmers | 144.2 | 363.3 | 88.7 | 277.5 | 55.5 | 85.8 |
| Drafters | 236.5 | 321.2 | 132.3 | 191.4 | 104.2 | 129.8 |
| Electrical/Electronics engineering | 241.9 | 374.5 | 135.1 | 236.4 | 106.8 | 138.1 |
| Mechanical engineering | 35.4 | 60.1 | 4 | 17.4 | 31.4 | 42.7 |
| Other Engineering | 183 | 293.5 | 95.3 | 184.5 | 87.7 | 109 |
| Science | 88.4 | 137.5 | 19.1 | 47.1 | 69.3 | 90.4 |

Note: Nonmanufacturing industries include mining, construction, finance, insurance, real estate, services, communications and utilities, wholesale trade, and retail trade.

SOURCE: National Science Foundation, Division of Science Resources Studies, Employment Studies Group

See figure 3-10. Science & Engineering Indicators—1987

**Appendix table 3-9. Percent of recent science and engineering (S/E) degree recipients employed in S/E jobs by degree and field: 1976, 1986**

| Field | Bachelor's 1976 | Bachelor's 1986 | Master's 1976 | Master's 1986 |
|---|---|---|---|---|
| | Percent | | | |
| Total | 44.7 | 63.8 | 77.4 | 84.3 |
| Physical Sciences | 58.9 | 68.0 | 67.5 | 85.7 |
| Mathematics | 45.9 | 73.6 | 61.5 | 89.7 |
| Computer Sciences | 90.0 | 89.2 | 85.4 | 90.0 |
| Engineering | 83.4 | 89.1 | 93.1 | 94.6 |
| Life Sciences | 49.7 | 56.7 | 75.9 | 80.6 |
| Social Sciences | 20.7 | 30.5 | 66.7 | 55.8 |

Note: Individuals enrolled full time in graduate school are excluded. Data for 1976 include 1974 and 1975 S/E graduates. Data for 1986 include 1984 and 1985 S/E graduates.

SOURCE: National Science Foundation, *Characteristics of Recent Science/Engineering Graduates: 1986* (forthcoming)

See figure 3-12. Science & Engineering Indicators—1987

**Appendix table 3-10. Science and engineering (S/E) degree recipients working as computer specialists in 1986, by field and year of degree**

| Field | Bachelor's 1984 | Bachelor's 1985 | Master's 1984 | Master's 1985 |
|---|---|---|---|---|
| Total | 35,600 | 41,900 | 8,000 | 8,800 |
| Physical Sciences | 700 | 200 | 100 | 100 |
| Mathematics | 3,900 | 3,600 | 400 | 400 |
| Computer Sciences | 24,200 | 29,800 | 6,000 | 6,800 |
| Engineering | 3,700 | 3,100 | 1,200 | 1,100 |
| Environmental Sciences | 100 | 100 | 100 | 100 |
| Life Sciences | 400 | 400 | (1) | 100 |
| Social Sciences | 1,900 | 4,000 | 200 | 200 |
| Psychology | 600 | 600 | (1) | 100 |

1 Too few cases to report.

Note: Detail may not add to totals due to rounding.

SOURCE: National Science Foundation, *Characteristics of Recent Science/Engineering Graduates, 1986* (forthcoming)

See figure 3-13. Science & Engineering Indicators—1987

## Appendix table 3-11. Employment status of doctoral scientists and engineers, by field and gender: 1973, 1981, 1985

| Field and gender | Total employed | | | Employed in S/E | | |
|---|---|---|---|---|---|---|
| | 1973 | 1981 | 1985 | 1973 | 1981 | 1985 |
| Total, all S/E fields | 220.300 | 344,000 | 400,400 | 208,300 | 314,500 | 365.500 |
| Men | 203,400 | 303,000 | 341.900 | 192.600 | 277,800 | 313,000 |
| Women | 16,900 | 41,000 | 58,500 | 15,700 | 36,800 | 52,500 |
| Total scientists | 184.600 | 286,900 | 334,500 | 173,800 | 261,400 | 304,100 |
| Men | 167,800 | 246,700 | 277,500 | 158,300 | 225.400 | 253,000 |
| Women | 16,800 | 40.200 | 57.000 | 15,500 | 36,000 | 51,100 |
| Physical scientists | 48,500 | 63.100 | 67,500 | 45,100 | 57,100 | 61,300 |
| Men | 46,500 | 59,300 | 62,800 | 43,400 | 53,800 | 57,100 |
| Women | 1,900 | 3,800 | 4,700 | 1,700 | 3,300 | 4.200 |
| Mathematical scientists | 12.100 | 15.600 | 16,800 | 11,800 | 14,100 | 15,500 |
| Men | 11,400 | 14,300 | 15,200 | 11.100 | 12,900 | 14,100 |
| Women | 800 | 1.300 | 1,600 | 700 | 1,200 | 1,400 |
| Computer specialists | 2,700 | 9.100 | 15,000 | 2,700 | 9,000 | 14,800 |
| Men | 2,600 | 8,400 | 13,400 | 2,600 | 8,300 | 13,200 |
| Women | 100 | 700 | 1,600 | 100 | 700 | 1,600 |
| Environmental scientists | 10,300 | 15,900 | 17.300 | 10,100 | 15,300 | 16,700 |
| Men | 10,100 | 15,100 | 16,200 | 9,900 | 14,500 | 15,600 |
| Women | 300 | 900 | 1,100 | 300 | 800 | 1,000 |
| Life scientists | 56,700 | 84,900 | 101,800 | 54,800 | 80,700 | 96,700 |
| Men | 50,600 | 71.600 | 82,100 | 49,000 | 68,300 | 78,200 |
| Women | 6,100 | 13,300 | 19,700 | 5,800 | 12,500 | 18,500 |
| Psychologists | 24,800 | 42,800 | 52,200 | 23,500 | 39,400 | 48,000 |
| Men | 20,000 | 31,100 | 35,600 | [illegible],000 | 28,700 | 32,600 |
| Women | 4,800 | 11,700 | 16,600 | 4,500 | 10,600 | 15,400 |
| Social scientists | 29,400 | 55,500 | 64.000 | 25.900 | 45,800 | 51,100 |
| Men | 26,500 | 47,000 | 52,200 | 23,400 | 38,900 | 42,200 |
| Women | 2,900 | 8,600 | 11,800 | 2,500 | 6,900 | 8,900 |
| Total engineers | 35,800 | 57,000 | 65,900 | 34,400 | 53,200 | 61,500 |
| Men | 35.600 | 56,300 | 64,400 | 34,300 | 52,400 | 60.000 |
| Women | 100 | 800 | 1,500 | 100 | 700 | 1,400 |
| Aeronautical/astronautical | 1,700 | 2,500 | 3,800 | 1,600 | 2,200 | 3,600 |
| Men | 1,700 | 2,500 | 3.700 | 1,600 | 2,200 | 3,500 |
| Women | (1) | (1) | 100 | (1) | (1) | 100 |
| Chemical | 4,500 | 7,100 | 7,100 | 4,200 | 6,400 | 6,300 |
| Men | 4,500 | 7,100 | 7,000 | 4,200 | 6,300 | 6.200 |
| Women | (1) | 100 | 100 | (1) | 100 | 100 |
| Civil | 3,100 | 6,100 | 6,400 | 3,000 | 5,500 | 5,900 |
| Men | 3,100 | 6,000 | 6,300 | 3,000 | 5,400 | 5.800 |
| Women | (1) | 100 | 100 | (1) | 100 | 100 |
| Electrical/electronics | 7,100 | 10,600 | 14,200 | 6,800 | 10,000 | 13,500 |
| Men | 7,000 | 10,500 | 13,900 | 6,800 | 9.900 | 13,200 |
| Women | (1) | 100 | 300 | (1) | 100 | 300 |
| Mechanical | 3,300 | 5,400 | 6,600 | 3,100 | 5,000 | 6,100 |
| Men | 3,300 | 5,300 | 6,500 | 3,100 | 4.900 | 6,100 |
| Women | (1) | (1) | 100 | (1) | (1) | (1) |
| Nuclear | 1,300 | 2,100 | 2,400 | 1,200 | 2,000 | 2,200 |
| Men | 1,300 | 2,000 | 2,300 | 1,200 | 2,000 | 2,200 |
| Women | (1) | (1) | (1) | (1) | (1) | (1) |
| Other engineers | 15,000 | 23.200 | 25,300 | 14,500 | 22,000 | 23,900 |
| Men | 14,900 | 22,800 | 24,500 | 14,500 | 21,700 | 23,100 |
| Women | 100 | 400 | 800 | 100 | 400 | 800 |

[1] Too few cases to estimate

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States* (biennial series)

See figures 3-14, 3-15, 3-16, and 3-19.

## Appendix table 3-12. Employed doctoral scientists and engineers, by field, gender, and primary work activity: 1973, 1985

| Field and gender | Total | | Primary work activity | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Research | | Development | | Management of R&D | | Management other than R&D | | Teaching | |
| | 1973 | 1985 | 1973 | 1985 | 1973 | 1985 | 1973 | 1985 | 1973 | 1985 | 1973 | 1985 |
| Total, all S/E fields | 220,300 | 400,400 | 63,000 | 132,500 | 8,500 | 22,000 | 26,200 | 35,000 | 13,200 | 34,700 | 79,900 | 111,700 |
| Men | 203,400 | 341,900 | 58,500 | 116,000 | 8,400 | 20,600 | 25,500 | 32,900 | 12,500 | 29,700 | 72,500 | 94,100 |
| Women | 16,900 | 58,500 | 4,500 | 16,500 | 200 | 1,400 | 700 | 2,100 | 800 | 5,000 | 7,500 | 17,600 |
| Total scientists | 184,600 | 334,500 | 54,700 | 106,700 | 3,500 | 11,200 | 19,300 | 24,000 | 11,000 | 29,200 | 71,100 | 99,200 |
| Men | 167,800 | 277,500 | 50,200 | 90,900 | 3,400 | 10,000 | 18,600 | 22,100 | 10,200 | 24,300 | 63,600 | 81,800 |
| Women | 16,800 | 57,000 | 4,500 | 15,800 | 100 | 1,200 | 700 | 1,900 | 800 | 4,900 | 7,400 | 17,400 |
| Physical scientists | 48,500 | 67,500 | 18,000 | 29,900 | 1,900 | 3,600 | 7,700 | 9,300 | 2,200 | 3,600 | 14,300 | 15,200 |
| Men | 46,600 | 62,800 | 17,400 | 27,900 | 1,900 | 3,400 | 7,600 | 9,000 | 2,100 | 3,400 | 13,400 | 13,900 |
| Women | 1,900 | 4,700 | 600 | 2,000 | (1) | 200 | 100 | 300 | 100 | 200 | 900 | 1,300 |
| Mathematical scientists | 12,100 | 16,800 | 2,500 | 4,000 | 200 | 600 | 400 | 400 | 500 | 1,300 | 8,000 | 9,400 |
| Men | 11,400 | 15,200 | 2,400 | 3,700 | 100 | 500 | 300 | 401 | 400 | 1,200 | 7,400 | 8,400 |
| Women | 800 | 1,600 | 100 | 300 | (1) | 100 | (1) | (1) | (1) | 100 | 600 | 1,000 |
| Computer specialists | 2,700 | 15,000 | 500 | 6,000 | 600 | 4,100 | 300 | 1,700 | 200 | 1,100 | 900 | 2,800 |
| Men | 2,600 | 13,400 | 500 | 5,400 | 500 | 3,700 | 300 | 1,500 | 200 | 1,000 | 900 | 2,600 |
| Women | 100 | 1,600 | (1) | 600 | (1) | 400 | (1) | 200 | (1) | 100 | (1) | 200 |
| Environmental scientists | 10,300 | 17,200 | 3,500 | 6,800 | 100 | 300 | 1,400 | 2,000 | 600 | 1,400 | 3,100 | 3,400 |
| Men | 10,100 | 16,100 | 3,400 | 6,300 | 100 | 301 | 1,400 | 1,900 | 600 | 1,300 | 3,000 | 3,200 |
| Women | 300 | 1,100 | 100 | 500 | (1) | (1) | (1) | 100 | (1) | 100 | 100 | 200 |
| Life scientists | 56,700 | 101,800 | 22,800 | 44,600 | 400 | 1,700 | 6,600 | 7,300 | [illegible] | 8,300 | 17,800 | 22,400 |
| Men | 50,600 | 81,800 | 20,000 | 35,800 | 400 | 1,400 | 6,300 | 6,600 | 2,400 | 6,700 | 15,600 | 17,400 |
| Women | 6,100 | 20,000 | 2,800 | 8,800 | (1) | 300 | 300 | 700 | 200 | 1,600 | 2,200 | 5,000 |
| Psychologists | 24,800 | 52,100 | 3,200 | 5,200 | 200 | 400 | 1,500 | 1,000 | 2,500 | 5,200 | 9,300 | 13,200 |
| Men | 20,000 | 35,100 | 2,700 | 3,700 | 100 | 300 | 1,400 | 700 | 2,200 | 3,800 | 7,500 | 9,400 |
| Women | 4,800 | 17,000 | 500 | 1,500 | (1) | 100 | 100 | 300 | 400 | 1,400 | 1,800 | 3,800 |
| Social scientists | 29,400 | 64,000 | 4,200 | 10,100 | 200 | 400 | 1,400 | 2,100 | 2,500 | 8,300 | 17,700 | 32,800 |
| Men | 26,500 | 52,200 | 3,800 | 8,100 | 100 | 300 | 1,300 | 1,700 | 2,400 | 6,900 | 15,800 | 26,900 |
| Women | 2,900 | 11,800 | 400 | 2,000 | (1) | 100 | 100 | 400 | 100 | 1,400 | 1,900 | 5,900 |
| Total engineers | 35,800 | 65,900 | 8,300 | 25,800 | 5,000 | 10,800 | 7,000 | 11,000 | 2,200 | 5,500 | 8,900 | 12,500 |
| Men | 35,600 | 64,400 | 8,200 | 25,100 | 4,900 | 10,500 | 6,900 | 10,800 | 2,200 | 5,400 | 8,800 | 12,200 |
| Women | 100 | 1,500 | (1) | 700 | (1) | 300 | (1) | 200 | (1) | 100 | (1) | 300 |
| Aeronautical/astronautical | 1,700 | 3,800 | 400 | 1,900 | 100 | 800 | 600 | 900 | 100 | 200 | 300 | 300 |
| Men | 1,700 | 3,700 | 400 | 1,900 | 100 | 800 | 600 | 900 | 100 | 200 | 300 | 300 |
| Women | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Chemical | 4,500 | 7,100 | 900 | 3,200 | 800 | 1,200 | 900 | 1,200 | 400 | 500 | 700 | 900 |
| Men | 4,500 | 7,000 | 900 | 3,100 | 800 | 1,200 | 900 | 1,200 | 400 | 500 | 700 | 900 |
| Women | (1) | 100 | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Civil | 3,100 | 6,400 | 400 | 1,400 | 200 | 500 | 300 | 500 | 300 | 700 | 1,300 | 2,200 |
| Men | 3,100 | 6,300 | 400 | 1,400 | 200 | 500 | 300 | 500 | 300 | 700 | 1,300 | 2,200 |
| Women | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Electrical/electronics | 7,100 | 14,200 | 1,400 | 5,300 | 1,400 | 2,900 | 1,400 | 2,900 | 300 | 1,300 | 2,000 | 3,000 |
| Men | 7,000 | 13,900 | 1,400 | 5,100 | 1,400 | 2,800 | 1,300 | 2,900 | 300 | 1,300 | 2,000 | 2,900 |
| Women | (1) | 300 | (1) | 200 | (1) | 100 | (1) | (1) | (1) | (1) | (1) | 100 |
| Materials | 4,500 | 7,300 | 1,500 | 3,300 | 400 | 600 | 1,200 | 1,500 | 100 | | 700 | 800 |
| Men | 4,400 | 7,100 | 1,500 | 3,200 | 400 | 600 | 1,200 | 1,400 | 100 | 400 | 700 | 800 |
| Women | (1) | 200 | (1) | 100 | (1) | (1) | (1) | 100 | (1) | (1) | (1) | (1) |
| Mechanical | 3,300 | 6,600 | 600 | 2,500 | 500 | 1,300 | 400 | 900 | 200 | 500 | 1,300 | 2,000 |
| Men | 3,300 | 6,500 | 600 | 2,500 | 500 | 1,300 | 400 | 900 | 200 | 500 | 1,300 | 2,000 |
| Women | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Nuclear | 1,300 | 2,400 | 200 | 1,100 | 200 | 500 | 300 | 300 | 100 | 300 | 200 | 100 |
| Men | 1,300 | 2,400 | 200 | 1,100 | 200 | 500 | 300 | 300 | 100 | 300 | 200 | 100 |
| Women | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) | (1) |
| Systems engineers | 2,000 | 3,700 | 400 | 1,900 | 300 | 1,100 | 300 | 600 | 100 | 200 | 400 | 400 |
| Men | 1,900 | 3,500 | 400 | 1,800 | 300 | 1,000 | 300 | 600 | 100 | 200 | 400 | 400 |
| Women | (1) | 200 | (1) | 100 | (1) | 100 | (1) | (1) | (1) | (1) | (1) | (1) |
| Other engineers | 8,600 | 14,300 | 2,400 | 5,400 | 1,000 | 1,800 | 1,700 | 2,100 | 600 | 1,400 | 1,900 | 2,600 |
| Men | 8,500 | 14,300 | 2,400 | 5,200 | 1,000 | 1,800 | 1,700 | 2,100 | 600 | 1,400 | 1,900 | 2,500 |
| Women | (1) | (1) | (1) | 200 | (1) | (1) | (1) | (1) | (1) | (1) | (1) | 100 |

[1] Too few cases to estimate

Note: Detail may not add to totals due to rounding

SOURCE: National Science Foundation. *Characteristics of Doctoral Scientists and Engineers in the United States* (biennial series)

See figure 3-17

## Appendix table 3-13. Selected employment characteristics of scientists and engineers, by field: 1986

| Field | Labor force participation rate | Unemployment rate | S/E Employment rate | S/E Underemployment rate | S/E Underutilization rate |
|---|---|---|---|---|---|
| | | | Percent | | |
| Total, all S/E fields | 94.5 | 1.5 | 84.7 | 2.6 | 4.1 |
| Total scientists | 95.3 | 1.9 | 76.7 | 4.3 | 6.1 |
| Physical scientists | 93.6 | 1.4 | 91.9 | 1.9 | 3.3 |
| Chemists | 94.1 | 3.2 | 91.5 | 1.8 | 5.0 |
| Physicists/astronomers | 95.1 | 1.1 | 94.1 | 1.2 | 2.2 |
| Other physical scientists | 95.1 | 1.9 | 89.1 | 3.3 | 5.2 |
| Mathematical scientists | 94.6 | 1.3 | 79.3 | 3.3 | 4.6 |
| Mathematicians | 94.5 | 1.1 | 77.7 | 3.4 | 4.5 |
| Statisticians | 95.2 | 2.4 | 87.8 | 3.0 | 5.3 |
| Computer specialists | 98.5 | 0.8 | 77.7 | 2.5 | 3.3 |
| Environmental scientists | 94.5 | 4.4 | 87.4 | 5.6 | 9.7 |
| Earth scientists | 94.4 | 5.0 | 86.3 | 6.1 | 10.8 |
| Oceanographers | 92.4 | 0.1 | 97.9 | 0.7 | 0.8 |
| Atmospheric scientists | 96.0 | 1.5 | 88.8 | 3.5 | 4.9 |
| Life scientists | 93.0 | 2.1 | 82.7 | 4.7 | 6.7 |
| Biological scientists | 92.9 | 2.2 | 83.5 | 5.2 | 7.3 |
| Agricultural scientists | 93.3 | 2.5 | 78.3 | 5.1 | 7.5 |
| Medical scientists | 93.9 | 0.4 | 89.5 | 0.1 | 0.5 |
| Psychologists | 95.1 | 2.5 | 68.2 | 5.7 | 8.1 |
| Social scientists | 95.4 | 2.4 | 60.7 | 7.2 | 9.4 |
| Economists | 95.5 | 3.1 | 61.3 | 5.6 | 8.5 |
| Sociologists/anthropologists | 95.3 | 2.2 | 61.2 | 9.2 | 11.1 |
| Other social scientists | 95.4 | 1.3 | 59.9 | 7.7 | 9.4 |
| Total Engineers | 93.8 | 1.2 | 91.9 | 1.0 | 2.2 |
| Aeronautical/astronautical | 94.7 | 0.4 | 94.3 | 0.6 | 1.0 |
| Chemical | 89.1 | 2.6 | 83.2 | 1.9 | 4.5 |
| Civil | 92.3 | 1.7 | 92.1 | 1.2 | 2.9 |
| Electrical/electronics | 93.5 | 1.1 | 94.1 | 0.8 | 1.8 |
| Industrial | 96.1 | 1.1 | 82.2 | 1.2 | 2.3 |
| Materials | 94.0 | 1.7 | 88.3 | 0.9 | 2.6 |
| Mechanical | 91.2 | 1.3 | 92.1 | 1.1 | 2.4 |
| Mining | 93.7 | 2.2 | 86.1 | 1.6 | 3.8 |
| Nuclear | 97.8 | 1.0 | 97.5 | 0.4 | 1.4 |
| Petroleum | 95.3 | 3.4 | 92.9 | 2.0 | 5.4 |
| Other engineers | 98.3 | 0.7 | 92.7 | 0.8 | 1.5 |

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures 3-20 and 3-21.

## Appendix table 3-14. Estimates and projections of the population by selected age group: 1950-2010

| Year | Total population | Age (Years) 18-24 | 25-34 |
|---|---|---|---|
| | ——— Thousands ——— | | |
| Estimates | | | |
| 1950 | 152,271 | 16,075 | 24,036 |
| 1955 | 165,931 | 14,968 | 24,283 |
| 1960 | 180,671 | 16,128 | 22,919 |
| 1965 | 194,303 | 20,293 | 22,465 |
| 1970 | 205,052 | 24,712 | 25,323 |
| 1975 | 215,973 | 28,005 | 31,471 |
| 1980 | 227,704 | 30,347 | 37,593 |
| Projections | | | |
| 1985 | 238,631 | 28,739 | 41,788 |
| 1990 | 249,657 | 25,794 | 43,529 |
| 1995 | 259,559 | 23,702 | 40,520 |
| 2000 | 267,995 | 24,601 | 36,415 |
| 2005 | 275,667 | 26,981 | 35,009 |
| 2010 | 283,238 | 27,665 | 36,978 |

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of the United States, by Age, Sex and Race: 1983-2080*, Series p-25, No. 952 (May 1984), table E, p. 7

See figure 3-23. Science & Engineering Indicators—1987

## Appendix table 3-15. Number of nonacademic scientists and engineers per 10,000 total labor force, by gender

| Country | Labor force | Scientists and engineers: Total | Men | Women | S/E per 10,000 labor force: Total | Men | Women |
|---|---|---|---|---|---|---|---|
| France (1982) | 23,525,120 | 387,860 | 346,020 | 41,840 | 165 | 147 | 18 |
| West Germany (1985) | 26,626,400 | 621,500 | 585,400 | 36,100 | 234 | 220 | 14 |
| Japan (1985) | 60,270,700 | 1,514,200 | 144,400 | 69,800 | 252 | 240 | 12 |
| United Kingdom (1981) | 25,405,590 | 653,140 | 583,330 | 69,810 | 257 | 230 | 27 |
| United States (1984) | 115,241,000 | 3,179,100 | 2,844,300 | 334,800 | 276 | 247 | 29 |

| Country | Labor force | Scientists: Total | Men | Women | Scientists per 10,000 labor force: Total | Men | Women |
|---|---|---|---|---|---|---|---|
| France (1982) | 23,525,120 | 139,980 | 107,100 | 32,880 | 60 | 46 | 14 |
| West Germany (1985) | 26,626,400 | 103,800 | 85,900 | 17,900 | 39 | 32 | 7 |
| Japan (1985) | 60,270,700 | 389,900 | 338,400 | 51,500 | 65 | 56 | 9 |
| United Kingdom (1981) | 25,405,590 | 287,690 | 223,830 | 63,860 | 113 | 88 | 25 |
| United States (1984) | 115,241,000 | 1,162,700 | 894,700 | 268,000 | 101 | 78 | 23 |

| Country | Labor force | Engineers: Total | Men | Women | Engineers per 10,000 labor force: Total | Men | Women |
|---|---|---|---|---|---|---|---|
| France (1982) | 23,525,120 | 247,880 | 238,920 | 8,960 | 105 | 102 | 4 |
| West Germany (1985) | 26,626,400 | 517,700 | 499,500 | 18,200 | 194 | 188 | 7 |
| Japan (1985) | 60,270,700 | 1,124,300 | 1,106,000 | 18,300 | 187 | 184 | 3 |
| United Kingdom (1981) | 25,405,590 | 365,450 | 359.500 | 5,950 | 144 | 142 | 2 |
| United States (1984) | 115,241,000 | 2,016,400 | 1,949,600 | 66,800 | 175 | 169 | 6 |

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-24. Science & Engineering Indicators—1987

## Appendix table 3-16. Distribution of scientists and engineers in manufacturing industry, by occupation group

| Country | Total | Scientists | Engineers | | |
|---|---|---|---|---|---|
| | | | Civil | Electrical Electronic | Industrial Mechanical |
| | Percent | | | | |
| United States (1985) | 100.0 | 16.6 | 1.0 | 26.3 | 56.1 |
| France (1982) | 100.0 | 22.9 | 3.5 | 20.5 | 53.1 |
| West Germany (1985) | 100.0 | 18.0 | 3.2 | 21.9 | 56.8 |
| Japan (1980) | 100.0 | 18.1 | 1.6 | 24.5 | 55.9 |
| United Kingdom (1981) | 100.0 | 25.9 | 1.0 | 14.1 | 59.0 |

Note: Figures for all countries exclude scientists and engineers in academic positions The Industrial Mechanical category includes all other engineers.

SOURCE: National Science Foundation. *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-25

Science & Engineering Indicators—1987

## Appendix table 3-17. Scientists and engineers engaged in R&D as a proportion of the total labor force population, by country: 1965-86

| Country | France | West Germany | Japan | United Kingdom | United States | U.S.S.R. Low Estimate | U.S.S.R. High Estimate |
|---|---|---|---|---|---|---|---|
| | S/E's in R&D, per 10,000 labor force population | | | | | | |
| 1965 | 21.0 | 22.7 | 24.6 | 19.6 | 64.7 | 44.8 | 48.2 |
| 1966 | 29.2 | 22.4 | 26.4 | NA | 66.9 | 47.1 | 51.4 |
| 1967 | 25.3 | 24.9 | 27.8 | NA | 67.2 | 50.7 | 55.3 |
| 1968 | 26.4 | 26.2 | 31.1 | 20.8 | 68.0 | 53.5 | 58.8 |
| 1969 | 27.1 | 28.4 | 30.8 | NA | 66.7 | 56.5 | 62.1 |
| 1970 | 27.3 | 30.8 | 33.4 | NA | 64.1 | 58.1 | 64.0 |
| 1971 | 27.9 | 33.4 | 37.5 | NA | 60.7 | 62.9 | 69.2 |
| 1972 | 28.2 | 35.6 | 38.1 | 30.4 | 58.0 | 67.1 | 74.2 |
| 1973 | 28.5 | 37.1 | 42.5 | NA | 56.4 | 71.0 | 79.1 |
| 1974 | 28.9 | 37.8 | 44.9 | NA | 55.6 | 74.2 | 82.6 |
| 1975 | 29.4 | 38.6 | 47.9 | 31.1 | 55.3 | 77.6 | 86.7 |
| 1976 | 29.9 | 39.2 | 48.4 | NA | 54.8 | 79.1 | 88.5 |
| 1877 | 30.0 | 41.8 | 49.9 | NA | 55.7 | 80.4 | 90.2 |
| 1978 | 31.0 | NA | 49.4 | 33.3 | 56.5 | 82.2 | 92.5 |
| 1979 | 31.6 | 45.3 | 50.4 | NA | 57.7 | 83.6 | 94.5 |
| 1980 | 32.4 | NA | 53.6 | NA | 60.0 | 85.7 | 97.1 |
| 1981 | 36.3 | 46.5 | 55.6 | 35.8 | 62.0 | 88.1 | 100.0 |
| 1982 | 37.9 | 47.0 | 57.1 | NA | 62.8 | 91.1 | 103.7 |
| 1983 | 39.1 | 48.4 | 58.1 | 35.1 | 63.8 | 92.4 | 105.9 |
| 1984 | 41.2 | 49.1 | 62.4 | 34.2 | 65.1 | 94.6 | 108.8 |
| 1985 | NA | NA | 63.2 | 32.8 | 67.4 | 96.9 | 111.6 |
| 1986 | NA | NA | NA | NA | 69.0 | NA | NA |

Note: NA Not Available

Note: Table includes all scientists and engineers engaged in research and development on a full-time basis except Japan, whose data include persons primarily employed in research and development, and the United Kingdom whose data include only the Government and industry sectors The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed in 1977 The figures for France increased in 1981 in part due to a re-evaluation of university research efforts

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure O-7 in Overview.

Science & Engineering Indicators—1987

## Appendix table 3-18. Distribution of scientists and engineers, by sector, for selected countries

| Country | Total | Manufacturing & mining | Construction | Services | Government |
|---|---|---|---|---|---|
| | Percent | | | | |
| United States (1985) | 100.0 | 51.0 | 2.5 | 36.5 | 10.0 |
| France (1982) | 100.0 | 44.4 | 7.3 | 17.9 | 30.4 |
| West Germany (1985) | 100.0 | 48.4 | 8.7 | 31.7 | 11.2 |
| Japan (1985) | 100.0 | 33.0 | 17.4 | 45.8 | 3.7 |
| United Kingdom (1981) | 100.0 | 49.2 | 5.7 | 36.1 | 8.9 |

Note: Figures for all countries exclude scientists and engineers in academic positions

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987*, (NSF 87-319)

See figure 3-26

Science & Engineering Indicators—1987

## Appendix table 3-19. Scientists and engineers engag[illegible] research and development, by country: 1965-86

| Country | France | West Germany | Japan | United Kingdom | United States | U.S.S.R. Low Estimate | U.S.S.R. High Estimate |
|---|---|---|---|---|---|---|---|
| | Thousands | | | | | | |
| 1965 | 42.8 | 61.0 | 117.6 | 49.9 | 494.6 | 521.8 | 561.4 |
| 1966 | 60.0 | 60.0 | 128.9 | NA | 521.1 | 556.5 | 607.6 |
| 1967 | 52.4 | 64.5 | 138.7 | NA | 534.4 | 607.8 | 662.6 |
| 1968 | 54.7 | 68.0 | 157.6 | 52.8 | 550.4 | 650.3 | 715.2 |
| 1969 | 57.2 | 74.9 | 157.1 | NA | 553.2 | 698.8 | 767.5 |
| 1970 | 58.5 | 82.5 | 172.0 | NA | 544.2 | 730.1 | 803.6 |
| 1971 | 60.1 | 90.2 | 194.3 | NA | 523.8 | 804.2 | 884.2 |
| 1972 | 61.2 | 96.0 | 198.1 | 76.7 | 515.3 | 872.3 | 964.5 |
| 1973 | 62.7 | 101.0 | 226.6 | NA | 514.8 | 938.9 | 1,045.1 |
| 1974 | 64.1 | 102.5 | 238.2 | NA | 520.8 | 997.0 | 1,110.6 |
| 1975 | 65.3 | 103.7 | 255.2 | 80.5 | 527.7 | 1,060.7 | 1,184.3 |
| 1976 | 67.0 | 104.5 | 260.2 | NA | 535.6 | 1,098.0 | 1,229.1 |
| 1877 | 68.0 | 111.0 | 272.0 | NA | 561.0 | 1,134.2 | 1,272.8 |
| 1978 | 70.9 | NA | 273.1 | 87.7 | 587.0 | 1,178.2 | 1,326.0 |
| 1979 | 72.9 | 122.0 | 281.9 | NA | 614.8 | 1,217.8 | 1,376.5 |
| 1980 | 74.9 | NA | 302.6 | NA | 651.7 | 1,262.4 | 1,430.4 |
| 1981 | 85.5 | 127.4 | 317.5 | 95.7 | 683.7 | 1,311.8 | 1,489.4 |
| 1982 | 90.1 | 129.0 | 329.7 | NA | 702.8 | 1,368.6 | 1,558.0 |
| 1983 | 92.7 | 133.1 | 342.2 | 94.1 | 722.9 | 1,399.0 | 1,603.0 |
| 1984 | 98.2 | 135.0 | 370.0 | 92.3 | 750.7 | 1,441.8 | 1,658.5 |
| 1985 | NA | NA | 381.3 | 90.0 | 790.0 | 1,485.3 | 1,710.5 |
| 1986 | NA | NA | 406.0 | NA | 825.0 | NA | NA |

Note: NA = Not Available.

Note: Table includes all scientists and engineers engaged in research and development on a full-time basis except Japan, whose data include persons primarily employed in research and development, and the United Kingdom whose data include only the Government and industry sectors. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed in 1977. The figures for France increased in 1981 in part due to a re-evaluation of university research efforts

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-27.

Science & Engineering Indicators—1987

## Appendix table 3-20. Distribution of scientists and engineers, by age group, for selected countries

| Country | Total | Under 35 | 35-54 | 55+ |
|---|---|---|---|---|
| | Percent | | | |
| United States (1984) | 100.0 | 27.6 | 53.3 | 19.0 |
| France (1982) | 100.0 | 29.6 | 58.4 | 12.1 |
| West Germany (1985) | 100.0 | 30.3 | 56.0 | 13.6 |
| Japan (1985) | 100.0 | 48.4 | 44.9 | 6.7 |
| United Kingdom (1981) | 100.0 | 45.2 | 42.4 | 12.5 |

Note: Figures for all countries exclude scientists and engineers in academic positions.

SOURCE. National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-28.

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## Appendix table 3-21. Employment status of scientists and engineers, by field and race: 1976, 1980, 1986

| Field and race | Total Employed | | | Employed in S/E | | |
|---|---|---|---|---|---|---|
| | 1976 | 1980 | 1986 | 1976 | 1980 | 1986 |
| Total, all S/E fields | 2,331,200 | 2,860,400 | 4,626,500 | 2,122,100 | 2,542,700 | 3,919,900 |
| White | 2,141,900 | 2,644,900 | 4,190,400 | 1,949,700 | 2,349,700 | 3,556,200 |
| Black | 38,100 | 57,600 | 114,900 | 34,900 | 50,900 | 87,900 |
| Asian | 106,600 | 121,000 | 226,800 | 98,500 | 112,000 | 199,000 |
| Other | 44,600 | 37,000 | 94,400 | 38,900 | 30,100 | 76,800 |
| Total scientists | 959,500 | 1,184,500 | 2,186,300 | 843,800 | 1,032,800 | 1,676,400 |
| White | 870,900 | 1,097,000 | 1,973,100 | 764,200 | 957,900 | 1,521,000 |
| Black | 21,400 | 30,500 | 73,700 | 19,400 | 26,000 | 50,600 |
| Asian | 48,500 | 41,500 | 94,000 | 43,100 | 37,500 | 72,300 |
| Other | 18,700 | 15,400 | 45,500 | 17,100 | 11,400 | 32,500 |
| Physical scientists | 188,900 | 215,200 | 288,400 | 154,900 | 166,300 | 264,900 |
| White | 172,400 | 201,200 | 261,800 | 141,200 | 155,600 | 240,400 |
| Black | 3,200 | 3,400 | 6,200 | 2,400 | 2,400 | 5,400 |
| Asian | 7,600 | 8,800 | 15,400 | 6,400 | 7,100 | 14,500 |
| Other | 5,700 | 1,800 | 5,000 | 4,900 | 1,200 | 4,600 |
| Mathematical scientists | 48,600 | 64,300 | 131,000 | 43,800 | 57,300 | 103,900 |
| White | 44,200 | 59,200 | 115,500 | 39,400 | 52,600 | 91,300 |
| Black | 2,600 | 2,900 | 6,800 | 2,500 | 2,500 | 6,100 |
| Asian | 1,600 | 2,100 | 5,900 | 1,700 | 2,100 | 4,200 |
| Other | 200 | 200 | 2,800 | 200 | 200 | 2,300 |
| Computer specialists | 119,000 | 207,800 | 562,600 | 116,000 | 196,700 | 437,200 |
| White | 110,700 | 192,000 | 497,100 | 108,000 | 181,500 | 388,200 |
| Black | 1,600 | 4,700 | 18,900 | 1,500 | 4,300 | 13,200 |
| Asian | 4,000 | 9,900 | 36,100 | 3,900 | 9,700 | 27,600 |
| Other | 2,700 | 1,300 | 10,500 | 2,600 | 1,200 | 8,200 |
| Environmental scientists | 54,800 | 77,600 | 111,300 | 46,600 | 63,100 | 97,300 |
| White | 48,300 | 70,000 | 105,800 | 40,700 | 57,700 | 93,600 |
| Black | 2,000 | 700 | 1,000 | 1,800 | 800 | 400 |
| Asian | 3,200 | 2,500 | 2,100 | 2,900 | 2,000 | 1,900 |
| Other | 1,200 | 4,400 | 2,400 | 1,200 | 2,700 | 1,400 |
| Life scientists | 213,500 | 287,500 | 411,800 | 198,200 | 267,300 | 340,500 |
| White | 200,700 | 270,300 | 377,900 | 186,100 | 250,700 | 313,300 |
| Black | 4,900 | 6,700 | 8,800 | 4,700 | 6,400 | 7,100 |
| Asian | 5,300 | 7,100 | 15,000 | 5,400 | 6,900 | 12,900 |
| Other | 2,500 | 3,400 | 10,100 | 2,000 | 3,400 | 7,200 |
| Psychologists | 112,500 | 128,100 | 253,500 | 103,700 | 112,500 | 172,800 |
| White | 105,100 | 121,600 | 234,100 | 97,100 | 107,400 | 161,800 |
| Black | 3,800 | 3,800 | 9,100 | 3,700 | 3,400 | 6,000 |
| Asian | 1,000 | 1,200 | 5,200 | 700 | 1,000 | 1,400 |
| Other | 2,600 | 1,500 | 5,100 | 2,100 | 800 | 3,600 |
| Social scientists | 222,300 | 204,000 | 427,800 | 180,500 | 169,700 | 259,800 |
| White | 189,400 | 182,800 | 380,800 | 151,600 | 152,600 | 232,600 |
| Black | 3,300 | 8,300 | 22,900 | 2,900 | 6,400 | 12,300 |
| Asian | 25,800 | 10,000 | 14,200 | 22,100 | 8,700 | 9,700 |
| Other | 3,800 | 2,900 | 9,900 | 3,900 | 2,000 | 5,200 |

(continued)

## Appendix table 3-21. (Continued)

| Field and race | Total Employed | | | Employed in S/E | | |
|---|---|---|---|---|---|---|
| | 1976 | 1980 | 1986 | 1976 | 1980 | 1986 |
| Total engineers | 1,371.700 | 1,675,900 | 2,440.100 | 1,278,300 | 1.509,900 | 2,243,500 |
| White | 1,271.000 | 1,547,800 | 2,217,300 | 1,185,500 | 1,391,700 | 2,035,200 |
| Black | 16,700 | 27,000 | 41.300 | 15,500 | 24,900 | 37,300 |
| Asian | 58,100 | 79,500 | 132,800 | 55,400 | 76,600 | 126.700 |
| Other | 25,900 | 21,600 | 48.700 | 21,900 | 18,700 | 44,300 |
| Aeronautical/astronautical | 56.800 | 69,500 | 110,500 | 55,700 | 65,000 | 104,200 |
| White | 54,100 | 65,000 | 100.800 | 52,900 | 60,500 | 94,900 |
| Black | 300 | 1,100 | 1,600 | 300 | 1,200 | 1,400 |
| Asian | 1,600 | 2,200 | 6,600 | 1,700 | 2,100 | 6,500 |
| Other | 700 | 1,200 | 1.500 | 700 | 1,200 | 1,400 |
| Chemical | 77,500 | 94,500 | 149,000 | 76.400 | 89,000 | 131,500 |
| White | 72,200 | 86,400 | 133,900 | 71,100 | 81,300 | 119,200 |
| Black | 1,500 | 800 | 2,000 | 1,500 | 400 | 900 |
| Asian | 2,400 | 5,800 | 10,100 | 2,400 | 5,700 | 9,200 |
| Other | 1.400 | 1,500 | 3,000 | 1,400 | 1,500 | 2,200 |
| Civil | 188,200 | 232.100 | 346,300 | 182.800 | 217,000 | 319,100 |
| White | 165,700 | 209,100 | 308.600 | 162,500 | 194,900 | 284,300 |
| Black | 1,600 | 3,900 | 5.200 | 1,800 | 3,800 | 4,800 |
| Asian | 14,800 | 16,000 | 24,500 | 14,800 | 15,200 | 23,300 |
| Other | 6,100 | 3,100 | 8.000 | 3,700 | 3,100 | 6,700 |
| Electrical/electronics | 283,000 | 383,100 | 574,500 | 267,900 | 357,400 | 540,800 |
| White | 262,500 | 346,500 | 512.500 | 248,800 | 323,600 | 481,800 |
| Black | 2.900 | 8,100 | 11,900 | 2,600 | 7,500 | 11,000 |
| Asian | 13,800 | 23,300 | 37,900 | 12,700 | 22,100 | 36,000 |
| Other | 3,800 | 5,100 | 12,200 | 3,800 | 4,200 | 12,000 |
| Mechanical | 276,200 | 322.600 | 492,600 | 272,800 | 30[illegible] 800 | 453,700 |
| White | 258,700 | 302,000 | 452,600 | 255,300 | 288,900 | 416,000 |
| Black | 2,400 | 2,700 | 6,700 | 2,200 | 2,500 | 6,400 |
| Asian | 9,700 | 13,900 | 24,600 | 9,600 | 13,600 | 23,400 |
| Other | 5,500 | 3,900 | 8,700 | 5,700 | 3,900 | 7,900 |
| Other engineers | 490,000 | 574,100 | 767,200 | 422.700 | 472,600 | 694,200 |
| White | 457,800 | 538,700 | 708,900 | 394,900 | 442,400 | 639,000 |
| Black | 8,000 | 10,300 | 13,900 | 7,000 | 9,400 | 12,800 |
| Asian | 15,800 | 18,300 | 29,100 | 14,300 | 15,900 | 28,300 |
| Other | 8,500 | 6,700 | 15,300 | 6,500 | 4,900 | 14,100 |

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure O-14 in Overview

## Appendix table 3-22. Employment status of Hispanic scientists and engineers, by field: 1986

| Field | Total employed | Employed in S/E |
|---|---|---|
| Total, all S/E fields | 93,400 | 74,900 |
| Total scientists | 46,100 | 31,200 |
| Physical scientists | 4,800 | 4,600 |
| Mathematical scientists | 3,100 | 2,600 |
| Computer specialists | 9,300 | 6,100 |
| Environmental scientists | 1,800 | 1,600 |
| Life scientists | 9,900 | 7,100 |
| Psychologists | 5,900 | 2,700 |
| Social scientists | 11,400 | 6,600 |
| Total engineers | 47,200 | 43,700 |
| Aeronautical/astronautical | 1,500 | 1,400 |
| Chemical | 2,700 | 2,500 |
| Civil | 7,300 | 7,100 |
| Electrical/electronics | 12,200 | 11,400 |
| Industrial | 2,500 | 2,300 |
| Materials | 400 | 400 |
| Mechanical | 9,000 | 7,900 |
| Mining | 100 | 100 |
| Nuclear | 100 | 100 |
| Petroleum | 700 | 700 |
| Other engineers | 10,700 | 9,900 |

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation. *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure O-14 in Overview. Science & Engineering Indicators—1987

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## Appendix table 3-23. First university degrees by major field of study and country: 1984 and 1985

| Academic fields | United States (1985) | | Japan (1985) | | West Germany (1984) | | United Kingdom (1984) | | France[1] (1984) | | Soviet Union[2] (1985) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| All fields | 990,877 | 100.0 | 373.302 | 100.0 | 57,153 | 100.0 | 73.841 | 100.0 | 46,248 | 100.0 | 858.900 | 100.0 |
| Natural sciences and engineering | 213,918 | 21.6 | 97.544 | 26.1 | 19,735 | 34.5 | 29,443 | 39.9 | 22,050 | 47.7 | 456,935 | 53.2 |
| Natural sciences | 120.168 | 12.1 | 12,698 | 3.4 | 9,429 | 16.5 | 17,400 | 23.6 | 9.350 | 20.2 | 52,395 | 6.1 |
| Engineering | 77,871 | 7.9 | 71,396 | 19.1 | 8,068 | 14.1 | 10,577 | 14.3 | 12,700 | 27.5 | 334,970 | 39.0 |
| Agriculture | 15,879 | 1.6 | 13,450 | 3.6 | 2,238 | 3.9 | 1,466 | 2.0 | ([3]) | ([3]) | 69,570 | 8.1 |
| Other | 776.959 | 78.4 | 275.758 | 73.9 | 37,418 | 65.5 | 44.398 | 60.1 | 24,198 | 52.3 | 401,965 | 46.8 |

[1] Data for France are based on maitrise degrees and engineering degrees. French engineering degrees are equivalent to U S master's degree

[2] Figures for the Soviet Union are estimates made to approximate the U.S. definitions

[3] Included in natural sciences.

NOTE: Percents are based on unrounded figures. Natural sciences include physical sciences. biological sciences and mathematics

Source: National Science Foundation. International Science and Technology Data Update 1987 (NSF 87-319)

See figure O-8 in Overview.

## Appendix table 4-1. National expenditures on research and development,[1] by source of funds, selected countries: 1970-86

| Country and source | 1970 | 1975 | 1979 | 1981 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|
| | Millions national currency | | | | | | | |
| United States | 26,134 | 35,213 | 54,933 | 71,840 | 87,204 | 97,639 | 107,462 | 116,793 |
| Domestic sources | 26,134 | 35,213 | 54,933 | 71,840 | 87,204 | 97,639 | 107,462 | 116,793 |
| Business Enterprises | 10,444 | 15,820 | 26,081 | 35,944 | 43,515 | 49,066 | 52,569 | 55,699 |
| Government | 14,892 | 18,109 | 26,815 | 33,405 | 40,671 | 45,341 | 51,330 | 57,219 |
| Non-profit | 337 | 535 | 837 | 971 | 1,137 | 1,208 | 1,304 | 1,375 |
| Universities | 461 | 749 | 1,200 | 1,520 | 1,881 | 2,024 | 2,259 | 2,500 |
| From abroad | NA | NA | NA | NA | NA | NA | NA | NA |
| Japan | 1,355,505 | 2,974,573 | 4,583,630 | 5,982,356 | 7,180,782 | 7,893,931 | 8,890,299 | NA |
| Domestic sources | 1,342,048 | 2,915,853 | 4,577,044 | 5,975,816 | 7,172,561 | 7,886,341 | NA | NA |
| Business Enterprises | 792,970 | 1,715,734 | 2,697,945 | 3,726,055 | 4,678,482 | 5,278,564 | 6,125,416 | NA |
| Government | 392,012 | 882,853 | 1,347,983 | 1,611,686 | 1,720,815 | 1,777,349 | 1,866,963 | NA |
| Non-profit | 4,887 | 20,812 | 16,525 | 41,857 | 46,396 | 55,175 | NA | NA |
| Universities | 152,179 | 296,454 | 514,591 | 596,218 | 726,868 | 775,253 | NA | NA |
| From abroad | 1,060 | 3,054 | 3,586 | 6,143 | 8,220 | 7,590 | NA | NA |
| West Germany | 13,903 | 22,968 | 33,457 | 37,703 | 42,512 | 44,200 | 49,000 | 53,400 |
| Domestic sources | 13,752 | 22,576 | 32,843 | 37,340 | 42,030 | NA | NA | NA |
| Business Enterprises | 7,419 | 11,514 | 18,540 | 21,860 | 25,144 | NA | 29,841 | NA |
| Government | 6,311 | 10,898 | 14,211 | 15,328 | 16,732 | NA | 18,424 | NA |
| Non-profit | 23 | 164 | 92 | 152 | 154 | NA | NA | NA |
| Universities | 0 | 0 | 0 | 0 | 0 | NA | NA | NA |
| From abroad | 151 | 392 | 613 | 363 | 482 | NA | NA | NA |
| France | 14,955 | 26,203 | 44,123 | 62,471 | 84,671 | 96,1[illegible]3 | 105,917 | 117,000 |
| Domestic sources | 14,775 | 24,747 | 41,830 | 59,277 | 81,658 | 92,[illegible]8 | NA | NA |
| Business Enterprises | 5,465 | 10,235 | 19,019 | 25,562 | 35,525 | 39,200 | 43,850 | NA |
| Government | 8,985 | 14,467 | 18,655 | 25,209 | 34,968 | 51,658 | 56,136 | NA |
| Non-profit | 21 | 30 | 267 | 233 | 363 | NA | NA | NA |
| Universities | 305 | 15 | 3,889 | 120 | 194 | NA | NA | NA |
| From abroad | 180 | 410 | 2.293 | 3,194 | 3,013 | 4,100 | NA | NA |
| United Kingdom[3] | 1,069 | 2,151 | 3,510 | 6,134 | 6,820 | NA | 8,150 | NA |
| Domestic sources | 1,019 | 2,038 | 3,281 | 5,692 | NA | NA | NA | NA |
| Business Enterprises | 453 | 823 | 1,484 | 2,529 | 2,869 | NA | 3,757 | NA |
| Government | 548 | 1,176 | 1,717 | 3,008 | 3,424 | NA | 3,537 | NA |
| Non-profit | 11 | 25 | 50 | 97 | 139 | NA | NA | NA |
| Universities | 7 | 15 | 30 | 58 | 36 | NA | NA | NA |
| From abroad | 47 | 105 | 212 | 411 | 348 | NA | NA | NA |

(continued)

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**Appendix table 4-1. (Continued)**

| Country and source | 1970 | 1975 | 1979 | 1981 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|
| | Millions U.S. 1982 constant dollars[2] | | | | | | | |
| United States | 62,179 | 59,371 | 69,916 | 76,458 | 83,963 | 90,633 | 96,665 | 102,405 |
| Domestic sources | 62,179 | 59,371 | 69,916 | 76,458 | 83,963 | 90,633 | 96,665 | 102,405 |
| Business Enterprises | 24,849 | 26,673 | 33,195 | 38,255 | 41,898 | 45,545 | 47,287 | 48,837 |
| Government | 35,432 | 30,533 | 34,129 | 35,552 | 39,159 | 42,088 | 46,173 | 50,170 |
| Non-profit | 802 | 902 | 1,065 | 1,033 | 1,095 | 1,121 | 1,173 | 1,206 |
| Universities | 1,097 | 1,263 | 1,527 | 1,618 | 1,811 | 1,879 | 2,032 | 2,192 |
| From abroad | NA | NA | NA | NA | NA | NA | NA | NA |
| Japan | 12,442 | 16,673 | 20,985 | 25,570 | 29,904 | 32,480 | 36,023 | NA |
| Domestic sources | 12,319 | 16,344 | 20,955 | 25,542 | 29,870 | 32,449 | NA | NA |
| Business Enterprises | 7,279 | 9,617 | 12,352 | 15,926 | 19,484 | 21,719 | 24,820 | NA |
| Government | 3,598 | 4,949 | 6,171 | 6,889 | 7,166 | 7,313 | 7,565 | NA |
| Non-profit | 45 | 117 | 76 | 179 | 193 | 227 | NA | NA |
| Universities | 1,397 | 1,662 | 2,356 | 2,548 | 3,027 | 3,190 | NA | NA |
| From abroad | 10 | 17 | 16 | 26 | 34 | 31 | NA | NA |
| West Germany | 9,880 | 11,894 | 14,858 | 15,357 | 16,071 | 16,385 | 17,773 | 18,789 |
| Domestic sources | 9,773 | 11,691 | 14,585 | 15,209 | 15,888 | NA | NA | NA |
| Business Enterprises | 5,272 | 5,962 | 8,233 | 8,904 | 9,505 | NA | 10,824 | NA |
| Government | 4,485 | 5,643 | 6,311 | 6,243 | 6,325 | NA | 6,683 | NA |
| Non-profit | 16 | 85 | 41 | 62 | 58 | NA | NA | NA |
| Universities | 0 | 0 | 0 | 0 | 0 | NA | NA | NA |
| From abroad | 107 | 203 | 272 | 148 | 182 | NA | NA | NA |
| France | 7,091 | 8,144 | 9,448 | 10,781 | 11,919 | 12,603 | 13,123 | 13,850 |
| Domestic sources | 7,006 | 7,691 | 8,957 | 10,230 | 11,495 | 12,066 | NA | NA |
| Business Enterprises | 2,591 | 3,181 | 4,072 | 4,411 | 5,001 | 5,136 | 5,433 | NA |
| Government | 4,260 | 4,496 | 3,994 | 4,350 | 4,922 | 6,768 | 6,955 | NA |
| Non-profit | 10 | 9 | 57 | 40 | 51 | NA | NA | NA |
| Universities | 145 | 5 | 833 | 21 | 27 | NA | NA | NA |
| From abroad | 85 | 127 | 491 | 551 | 424 | 537 | NA | NA |
| United Kingdom[3] | 8,726 | 9,496 | 9,288 | 12,155 | 11,946 | NA | 12,930 | NA |
| Domestic sources | 8,317 | 8,997 | 8,682 | 11,278 | NA | NA | NA | NA |
| Business Enterprises | 3,701 | 3,631 | 3,926 | 5,011 | 5,025 | NA | 5,961 | NA |
| Government | 4,473 | 5,191 | 4,544 | 5,959 | 5,997 | NA | 5,611 | NA |
| Non-profit | 90 | 109 | 133 | 192 | 243 | NA | NA | NA |
| Universities | 54 | 65 | 79 | 115 | 63 | NA | NA | NA |
| From abroad | 380 | 464 | 562 | 814 | 610 | NA | NA | NA |

Note: NA = not available.

[1] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States where total capital expenditure data are not available.

[2] Data are deflated using the implicit GDP price deflator, except for the United States, for which the GNP deflator is used. Deflated data are transformed into dollars using the 1975 purchasing power parity.

[3] United Kingdom data for 1970 are for fiscal year 1969/70, and 1979 for fiscal year 1978/79.

SOURCES: OECD, *Science and Technology Indicators Recent Results*, September. 1987, National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming); National Science Foundation, unpublished statistics

See figures O-1 and O-4 in Overview.

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## Appendix table 4-2. National expenditures for performance of R&D[1] as a percent of gross national product (GNP),[2] by country: 1970-87

| Year | France | West Germany | Japan | United Kingdom | United States | Soviet Union |
|---|---|---|---|---|---|---|
| | National expenditures on R&D as a percent of GNP | | | | | |
| 1970 | 1.91 | 2.06 | 1.85 | 2.07 | 2.57 | 3.28 |
| 1971 | 1.90 | 2.19 | 1.85 | NA | 2.42 | 3.46 |
| 1972 | 1.90 | 2.20 | 1.86 | 2.11 | 2.35 | 3.71 |
| 1973 | 1.76 | 2.09 | 1.90 | NA | 2.26 | 3.81 |
| 1974 | 1.79 | 2.13 | 1.97 | NA | 2.23 | 3.74 |
| 1975 | 1.80 | 2.22 | 1.96 | 2.19 | 2.20 | 3.78 |
| 1976 | 1.77 | 2.15 | 1.95 | NA | 2.19 | 3.61 |
| 1977 | 1.76 | 2.14 | 1.93 | NA | 2.15 | 3.54 |
| 1978 | 1.76 | 2.24 | 2.00 | 2.24 | 2.14 | 3.54 |
| 1979 | 1.81 | 2.40 | 2.09 | NA | 2.19 | 3.59 |
| 1980 | 1.84 | 2.42 | 2.22 | NA | 2.29 | 3.76 |
| 1981 | 2.01 | 2.44 | 2.38 | 2.41 | 2.35 | 3.75 |
| 1982 | 2.10 | 2.59 | 2.47 | NA | 2.51 | 3.68 |
| 1983 | 2.15 | 2.54 | 2.61 | 2.25 | 2.56 | 3.82 |
| 1984 | 2.25 | 2.52 | 2.61 | NA | 2.59 | 3.95 |
| 1985 | 2.31 | 2.67 | 2.77 | 2.42 | 2.69 | 3.74 |
| 1986 | 2.41 | 2.74 | NA | NA | 2.72 | 3.79 |
| 1987 | NA | NA | NA | NA | 2.77 | NA |
| | National expenditures on R&D national currency in millions | | | | | |
| 1970 | 14,955 | 13,903 | 1,355,505 | 1,069 | 26,134 | 11,700 |
| 1971 | 16,621 | 16,527 | 1,532,372 | NA | 26,676 | 13,000 |
| 1972 | 18,277 | 18,212 | 1,791,879 | 1,350 | 28,477 | 14,400 |
| 1973 | 19,789 | 19,232 | 2,215,837 | NA | 30,718 | 15,700 |
| 1974 | 23,031 | 20,990 | 2,716,032 | NA | 32,864 | 16,500 |
| 1975 | 26,203 | 22,968 | 2,974,573 | 2,300 | 35,213 | 17,400 |
| 1976 | 29,774 | 24,150 | 3,320,288 | NA | 39,018 | 17,700 |
| 1977 | 33,185 | 25,733 | 3,651,319 | NA | 42,783 | 18,300 |
| 1978 | 37,671 | 28,900 | 4,045,864 | 3,680 | 48,129 | 19,300 |
| 1979 | 44,123 | 33,457 | 4,583,630 | NA | 54,933 | 20,200 |
| 1980 | 51,014 | 35,903 | 5,246,247 | NA | 62,593 | 22,300 |
| 1981 | 62,471 | 37,703 | 5,982,356 | 6,134 | 71,840 | 23,400 |
| 1982 | 74,836 | 41,300 | 6,528,701 | NA | 79,328 | 24,600 |
| 1983 | 84,671 | 42,512 | 7,180,782 | 6,820 | 87,204 | 25,700 |
| 1984 | 96,198 | 44,200 | 7,893,931 | NA | 97,639 | 27,600 |
| 1985 | 105,917 | 49,000 | 8,890,299 | 8,150 | 107,642 | 27,500 |
| 1986 | 117,000 | 53,400 | NA | NA | 116,793 | 29,000 |
| 1987 | NA | NA | NA | NA | 124,250 | NA |
| | Gross national product national currency in billions | | | | | |
| 1970 | 782.0 | 676.0 | 73,128.0 | 51.6 | 1,015.5 | 356.2 |
| 1971 | 873.1 | 756.0 | 82,725.8 | 57.8 | 1,102.7 | 375.7 |
| 1972 | 961.3 | 827.2 | 96,424.0 | 63.9 | 1,212.8 | 388.6 |
| 1973 | 1,121.3 | 920.1 | 116,636.3 | 74.2 | 1,359.3 | 412.2 |
| 1974 | 1,284.4 | 986.9 | 138,044.6 | 84.3 | 1,472.8 | 441.0 |
| 1975 | 1,452.0 | 1,034.9 | 151,797.0 | 105.2 | 1,598.4 | 460.5 |
| 1976 | 1,677.8 | 1,125.0 | 170,290.0 | 125.7 | 1,782.8 | 490.0 |
| 1977 | 1,885.0 | 1,200.0 | 188,804.3 | 143.2 | 1,990.5 | 516.6 |
| 1978 | 2,141.0 | 1,290.7 | 202,708.0 | 164.6 | 2,249.7 | 545.1 |
| 1979 | 2,442.0 | 1,395.3 | 218,894.0 | 191.1 | 2,508.2 | 563.2 |
| 1980 | 2,765.0 | 1,484.2 | 235,834.0 | 229.5 | 2,732.0 | 593.1 |
| 1981 | 3,110.6 | 1,545.1 | 251,259.0 | 254.8 | 3,052.6 | 624.2 |
| 1982 | 3,567.0 | 1,597.1 | 263,984.0 | 278.1 | 3,166.0 | 667.8 |
| 1983 | 3,935.0 | 1,674.1 | 274,639.0 | 303.2 | 3,401.6 | 672.9 |
| 1984 | 4,277.2 | 1,756.9 | 303,019.8 | 322.7 | 3,774.7 | 699.3 |
| 1985 | 4,579.6 | 1,837.9 | 320,774.8 | 337.0 | 3,996.7 | 735.5 |
| 1986 | 4,857.2 | 1,949.0 | 330,712.7 | NA | 4,291.0 | 765.0 |
| 1987 | NA | NA | NA | NA | 4,491.3 | NA |

Note: NA = Not available.

Note: The latest data may be preliminary or estimates The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed prior to 1977.

[1] Gross expenditures for performance of R&D including associated capital expenditures except for the United States where total capital expenditure data are not available. U S. estimates for the period 1972-80 show that the inclusion of capital expenditures would have an impact of less than one percent of the R&D/GNP ratio.
[2] Gross domestic product is used for France.

SOURCES: GNP data: International Monetary Fund, *International Financial Statistics*, vol 30 (May 1977), vol 31 (May 1978), vol 31 (August 1978), vol 32 (January 1979), and vol 33 (August 1980), U S Department of Commerce, *International Economic Indicators* (June 1984) International R&D expenditure data OECD, *Science and Technology Indicators Recent Results, 1981-87*, September, 1987 and OECD, Science, Technology and Industry Indicators Division, unpublished statistics, Soviet Union: unpublished statistics provided by Robert Campbell, Indiana University United States Division of Science Resources Studies, National Science Foundation. *National Patterns of Science and Technology Resources. 1987* (forthcoming)

See figure O-2 in Overview.

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## Appendix table 4-3. Estimated non-defense R&D expenditures[1] as a percent of gross national product (GNP),[2] by country: 1971-87

| Year | France | West Germany | Japan | United Kingdom | United States |
|---|---|---|---|---|---|
| | Estimated non-defense R&D expenditures as a percent of GNP | | | | |
| 1971 | NA | 2.03 | 1.84 | NA | 1.65 |
| 1972 | 1.58 | 2.08 | 1.84 | 1.56 | 1.60 |
| 1973 | 1.38 | 1.94 | 1.89 | NA | 1.58 |
| 1974 | 1.43 | 1.98 | 1.96 | NA | 1.63 |
| 1975 | 1.46 | 2.08 | 1.95 | 1.55 | 1.63 |
| 1976 | 1.44 | 2.01 | 1.94 | NA | 1.62 |
| 1977 | 1.44 | 2.01 | 1.92 | NA | 1.61 |
| 1978 | 1.41 | 2.10 | 1.98 | 1.61 | 1.63 |
| 1979 | 1.42 | 2.27 | 2.08 | NA | 1.69 |
| 1980 | 1.43 | 2.30 | 2.21 | NA | 1.79 |
| 1981 | 1.50 | 2.34 | 2.37 | 1.72 | 1.81 |
| 1982 | 1.63 | 2.48 | 2.46 | NA | 1.88 |
| 1983 | 1.69 | 2.43 | 2.60 | 1.60 | 1.87 |
| 1984 | 1.76 | 2.41 | 2.59 | NA | 1.86 |
| 1985 | 1.85 | 2.53 | 2.75 | 1.71 | 1.86 |
| 1986 | 1.94 | 2.60 | NA | NA | 1.85 |
| 1987 | NA | NA | NA | NA | 1.88 |
| | Estimated non-defense R&D expenditures national currency in billions | | | | |
| 1971 | NA | 15.3 | 1,520.1 | NA | 18.1 |
| 1972 | 15.2 | 17.2 | 1,777.8 | 1.0 | 19.4 |
| 1973 | 15.4 | 17.9 | 2,200.2 | NA | 21.5 |
| 1974 | 18.4 | 19.6 | 2,699.8 | NA | 24.0 |
| 1975 | 21.2 | 21.6 | 2,957.5 | 1.6 | 26.1 |
| 1976 | 24.2 | 22.7 | 3,301.4 | NA | 28.9 |
| 1977 | 27.1 | 24.1 | 3,629.3 | NA | 32.1 |
| 1978 | 30.2 | 27.2 | 4,021.7 | 2.7 | 36.6 |
| 1979 | 34.8 | 31.6 | 4,556.9 | NA | 42.3 |
| 1980 | 39.7 | 34.2 | 5,217.2 | NA | 48.8 |
| 1981 | 46.8 | 36.1 | 5,950.1 | 4.4 | 55.3 |
| 1982 | 58.1 | 39.7 | 6,493.1 | NA | 59.5 |
| 1983 | 66.6 | 40.7 | 7,140.3 | 4.8 | 63.7 |
| 1984 | 75.4 | 42.3 | 7,848.1 | NA | 70.3 |
| 1985 | 84.8 | 46.5 | 8,830.0 | 5.8 | 74.3 |
| 1986 | 94.3 | 50.7 | NA | NA | 79.4 |
| 1987 | NA | NA | NA | NA | 84.5 |
| | Gross national product national currency in billions | | | | |
| 1971 | 873.1 | 756.0 | 82,725.8 | 57.8 | 1,102.7 |
| 1972 | 961.3 | 827.2 | 96,424.0 | 63.9 | 1,212.8 |
| 1973 | 1,121.3 | 920.1 | 116,636.3 | 74.2 | 1,359.3 |
| 1974 | 1,284.4 | 986.9 | 138,044.6 | 84.3 | 1,472.8 |
| 1975 | 1,452.0 | 1,034.9 | 151,797.0 | 105.2 | 1,598.4 |
| 1976 | 1,677.8 | 1,125.0 | 170,290.0 | 125.7 | 1,782.8 |
| 1977 | 1,885.0 | 1,200.0 | 188,804.3 | 143.2 | 1,990.5 |
| 1978 | 2,141.0 | 1,290.7 | 202,708.0 | 164.6 | 2,249.7 |
| 1979 | 2,442.0 | 1,395.3 | 218,894.0 | 191.1 | 2,508.2 |
| 1980 | 2,765.0 | 1,484.2 | 235,834.0 | 229.5 | 2,732.0 |
| 1981 | 3,110.6 | 1,545.1 | 251,259.0 | 254.8 | 3,052.6 |
| 1982 | 3,567.0 | 1,597.1 | 263,984.0 | 278.1 | 3,166.0 |
| 1983 | 3,935.0 | 1,674.1 | 274,639.0 | 303.2 | 3,401.6 |
| 1984 | 4,277.2 | 1,756.9 | 303,019.8 | 322.7 | 3,774.7 |
| 1985 | 4,579.6 | 1,837.9 | 320,774.8 | 337.0 | 3,996.7 |
| 1986 | 4,857.2 | 1,949.0 | 330,712.7 | NA | 4,291.0 |
| 1987 | NA | NA | NA | NA | 4,491.3 |

Note: NA = Not available.

Note: The latest data may be preliminary or estimates. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed prior to 1977.

[1] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States, where total capital expenditure data are not available. U.S. estimates for the period 1972-80 show that the inclusion of capital expenditures would have an impact of less than one tenth of one percent of the R&D/GNP ratio.

[2] Gross domestic product is used for France.

SOURCES: GNP data: International Monetary Fund, *International Financial Statistics*, vol. 30 (May 1977), vol. 31 (May 1978), vol 31 (August 1978), vol 32 (January 1979), and vol. 33 (August 1980). U.S. Department of Commerce, *International Economic Indicators* (June 1984), international R&D expenditure data OECD, *Science and Technology Indicators Recent Results, 1981-87*, September, 1987 and OECD, Science, Technology and Industry Indicators Division, unpublished statistics; United States: Division of Science Resources Studies, National Science Foundation. *National Patterns of Science and Technology Resources*, 1987 (forthcoming)

See figure O-3 in Overview.

## Appendix table 4-4. Research and development, by performer: 1960-87

| Year | Total | Federal | Industry | U&C | FFRDC's | Nonprofit institutions | Total | Federal | Industry | U&C | FFRDC's | Nonprofit institutions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | Millions constant 1982 dollars[1] | | | | | |
| 1960 ..... | 13,523 | 1,726 | 10,509 | 646 | 360 | 282 | 43,693 | 5,577 | 33,955 | 2,087 | 1,163 | 911 |
| 1961 ..... | 14,316 | 1,874 | 10,908 | 763 | 410 | 361 | 45,826 | 5,999 | 34,917 | 2,442 | 1,312 | 1,156 |
| 1962 ..... | 15,394 | 2,098 | 11,464 | 904 | 470 | 458 | 48,197 | 6,569 | 35,892 | 2,830 | 1,472 | 1,434 |
| 1963 ..... | 17,059 | 2,279 | 12,630 | 1,081 | 530 | 539 | 52,651 | 7,034 | 38,981 | 3,336 | 1,636 | 1,664 |
| 1964 ..... | 18,854 | 838 | 13,512 | 1,275 | 629 | 600 | 57,255 | 8,618 | 41,032 | 3,872 | 1,910 | 1,822 |
| 1965 ..... | 20,044 | 3,093 | 14,185 | 1,474 | 629 | 663 | 59,337 | 9,156 | 41,992 | 4,364 | 1,862 | 1,963 |
| 1966 ..... | 21,846 | 3,220 | 15,548 | 1,715 | 630 | 733 | 62,489 | 9,211 | 44,474 | 4,906 | 1,802 | 2,097 |
| 1967 ..... | 23,146 | 3,396 | 16,385 | 1,921 | 673 | 771 | 64,402 | 9,449 | 45,590 | 5,345 | 1,873 | 2,145 |
| 1968 ..... | 24,605 | 3,494 | 17,429 | 2,149 | 719 | 814 | 65,213 | 9,261 | 46,194 | 5,696 | 1,906 | 2,157 |
| 1969 ..... | 25,631 | 3,503 | 18,308 | 2,225 | 725 | 870 | 64,432 | 8,806 | 46,023 | 5,593 | 1,823 | 2,187 |
| 1970 ..... | 26,134 | 4,079 | 18,067 | 2,335 | 737 | 916 | 62,179 | 9,705 | 42,986 | 5,556 | 1,754 | 2,179 |
| 1971 ..... | 26,676 | 4,228 | 18,320 | 2,500 | 716 | 912 | 60,108 | 9,527 | 41,280 | 5,633 | 1,613 | 2,055 |
| 1972 ..... | 28,477 | 4,590 | 19,552 | 2,630 | 753 | 952 | 61,254 | 9,373 | 42,056 | 5,657 | 1,620 | 2,048 |
| 1973 ..... | 30,718 | 4,762 | 21,249 | 2,884 | 817 | 1,006 | 62,006 | 9,612 | 42,893 | 5,822 | 1,649 | 2,031 |
| 1974 ..... | 32,864 | 4,911 | 22,887 | 3,023 | 865 | 1,178 | 60,904 | 9,101 | 42,415 | 5,602 | 1,603 | 2,183 |
| 1975 ..... | 35,213 | 5,354 | 24,187 | 3,409 | 987 | 1,276 | 59,371 | 9,027 | 40,781 | 5,748 | 1,664 | 2,151 |
| 1976 ..... | 39,018 | 5,769 | 26,997 | 3,729 | 1,147 | 1,376 | 61,865 | 9,147 | 42,805 | 5,912 | 1,819 | 2,182 |
| 1977 ..... | 42,783 | 6,012 | 29,825 | 4,067 | 1,384 | 1,495 | 63,589 | 8,936 | 44,330 | 6,045 | 2,057 | 2,222 |
| 1978 ..... | 48,129 | 6,811 | 33,304 | 4,625 | 1,717 | 1,672 | 66,642 | 9,431 | 46,115 | 6,404 | 2,377 | 2,315 |
| 1979 ..... | 54,933 | 7,417 | 38,226 | 5,361 | 1,935 | 1,994 | 69,916 | 9,440 | 48,652 | 6,823 | 2,463 | 2,538 |
| 1980 ..... | 62,593 | 7,632 | 44,505 | 6,060 | 2,246 | 2,150 | 73,020 | 8,903 | 51,919 | 7,070 | 2,620 | 2,508 |
| 1981 ..... | 71,840 | 8,425 | 51,810 | 6,819 | 2,486 | 2,300 | 76,458 | 8,967 | 55,140 | 7,257 | 2,646 | 2,448 |
| 1982 ..... | 79,316 | 9,141 | 57,995 | 7,267 | 2,479 | 2,425 | 79,316 | 9,141 | 57,995 | 7,267 | 2,479 | 2,425 |
| 1983 ..... | 87,204 | 10,582 | 63,403 | 7,807 | 2,737 | 2,675 | 83,963 | 10,189 | 61,047 | 7,517 | 2,635 | 2,576 |
| 1984 ..... | 97,639 | 11,572 | 71,471 | 8,503 | 3,118 | 2,975 | 90,633 | 10,742 | 66,343 | 7,893 | 2,894 | 2,762 |
| 1985 ..... | 107,462 | 12,998 | 78,181 | 9,504 | 3,529 | 3,250 | 96,665 | 11,692 | 70,326 | 8,549 | 3,174 | 2,923 |
| 1986 ..... | 116,793 | 13,533 | 85,660 | 10,600 | 3,600 | 3,400 | 102,405 | 11,866 | 75,107 | 9,294 | 3,157 | 2,981 |
| 1987 ..... | 124,250 | 15,000 | 90,700 | 11,150 | 3,800 | 3,600 | 105,422 | 12,727 | 76,956 | 9,460 | 3,224 | 3,054 |

[1] GNP implicit price deflator used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

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## Appendix table 4-5. Research and development, by source and performer: 1960-87

| Year | Total | Federal[1] | Industry[1] | | | Universities and colleges[1] | | | | | FFRDC | Nonprofit institutions[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Federal | Industry | Total | Federal | Industry | U&C | NP | | Total | Federal | Industry | NP |
| | Millions of dollars | | | | | | | | | | | | | | |
| 1960 ... | 13,523 | 1,726 | 10,509 | 6,081 | 4,428 | 646 | 405 | 40 | 149 | 52 | 360 | 282 | 166 | 48 | 68 |
| 1961 ... | 14,316 | 1,874 | 10,908 | 6,240 | 4,668 | 763 | 500 | 40 | 165 | 58 | 410 | 361 | 226 | 49 | 86 |
| 1962 ... | 15,394 | 2,098 | 11,464 | 6,435 | 5,029 | 904 | 613 | 40 | 185 | 66 | 470 | 458 | 295 | 54 | 109 |
| 1963 ... | 17,059 | 2,279 | 12,630 | 7,270 | 5,360 | 1,081 | 760 | 41 | 207 | 73 | 530 | 539 | 365 | 55 | 119 |
| 1964 ... | 18,854 | 2,838 | 13,512 | 7,720 | 5,792 | 1,275 | 917 | 40 | 235 | 83 | 629 | 600 | 433 | 55 | 112 |
| 1965 ... | 20,044 | 3,093 | 14,185 | 7,740 | 6,445 | 1,474 | 1,073 | 41 | 267 | 93 | 629 | 663 | 477 | 62 | 124 |
| 1966 ... | 21,846 | 3,220 | 15,548 | 8,332 | 7,216 | 1,715 | 1,261 | 42 | 304 | 108 | 630 | 733 | 525 | 70 | 138 |
| 1967 ... | 23,146 | 3,396 | 16,385 | 8,365 | 8,020 | 1,921 | 1,409 | 48 | 345 | 119 | 673 | 771 | 552 | 74 | 145 |
| 1968 ... | 24,605 | 3,494 | 17,429 | 8,560 | 8,869 | 2,149 | 1,573 | 55 | 390 | 131 | 719 | 814 | 582 | 81 | 151 |
| 1969 ... | 25,631 | 3,503 | 18,308 | 8,451 | 9,857 | 2,225 | 1,600 | 60 | 420 | 145 | 725 | 870 | 616 | 93 | 161 |
| 1970 ... | 26,134 | 4,079 | 18,067 | 7,779 | 10,288 | 2,335 | 1,648 | 61 | 461 | 165 | 737 | 916 | 649 | 95 | 172 |
| 1971 ... | 26,676 | 4,228 | 18,320 | 7,666 | 10,654 | 2,500 | 1,724 | 70 | 529 | 177 | 716 | 912 | 630 | 98 | 184 |
| 1972 ... | 28,477 | 4,590 | 19,552 | 8,017 | 11,535 | 2,630 | 1,795 | 74 | 574 | 187 | 753 | 952 | 653 | 101 | 198 |
| 1973 ... | 30,718 | 4,762 | 21,249 | 8,145 | 13,104 | 2,884 | 1,985 | 84 | 613 | 202 | 817 | 1,006 | 690 | 105 | 211 |
| 1974 ... | 32,864 | 4,911 | 22,887 | 8,220 | 14,667 | 3,023 | 2,032 | 96 | 677 | 218 | 865 | 1,178 | 822 | 115 | 241 |
| 1975 ... | 35,213 | 5,354 | 24,187 | 8,605 | 15,582 | 3,409 | 2,288 | 113 | 749 | 259 | 987 | 1,276 | 875 | 125 | 276 |
| 1976 ... | 39,018 | 5,769 | 26,997 | 9,561 | 17,436 | 3,729 | 2,512 | 123 | 810 | 284 | 1,147 | 1,376 | 925 | 135 | 316 |
| 1977 ... | 42,783 | 6,012 | 29,825 | 10,485 | 19,340 | 4,067 | 2,726 | 139 | 888 | 314 | 1,384 | 1,495 | 987 | 150 | 358 |
| 1978 ... | 48,129 | 6,811 | 33,304 | 11,189 | 22,115 | 4,625 | 3,059 | 170 | 1,037 | 359 | 1,717 | 1,672 | 1,100 | 165 | 407 |
| 1979 ... | 54,933 | 7,417 | 38,226 | 12,518 | 25,708 | 5,361 | 3,595 | 193 | 1,200 | 373 | 1,935 | 1,994 | 1,350 | 180 | 464 |
| 1980 ... | 62,[illegible]93 | 7,632 | 44,505 | 14,029 | 30,476 | 6,060 | 4,094 | 235 | 1,323 | 408 | 2,246 | 2,150 | 1,450 | 200 | 500 |
| 1981 ... | 71,840 | 8,425 | 51,810 | 16,382 | 35,428 | 6,819 | 4,562 | 291 | 1,520 | 446 | 2,486 | 2,300 | 1,550 | 225 | 525 |
| 1982 ... | 79,316 | 9,141 | 57,995 | 18,483 | 39,512 | 7,267 | 4,752 | 334 | 1,690 | 500 | 2,479 | 2,425 | 1,650 | 250 | 525 |
| 1983 ... | 87,204 | 10,582 | 63,403 | 20,542 | 42,861 | 7,807 | 4,960 | 379 | 1,881 | 587 | 2,737 | 2,675 | 1,850 | 275 | 550 |
| 1984 ... | 97,639 | 11,572 | 71,471 | 23,163 | 48,308 | 8,503 | 5,388 | 458 | 2,024 | 633 | 3,118 | 2,975 | 2,100 | 300 | 575 |
| 1985 ... | 107,462 | 12,998 | 78,181 | 26,485 | 51,696 | 9,504 | 6,003 | 538 | 2,259 | 704 | 3,529 | 3,250 | 2,315 | 335 | 600 |
| 1986 ... | 116,793 | 13,533 | 85,660 | 30,936 | 54,724 | 10,600 | 6,750 | 600 | 2,500 | 750 | 3,600 | 3,400 | 2,400 | 375 | 625 |
| 1987 ... | 124,250 | 15,000 | 90,700 | 33,000 | 57,700 | 11,150 | 7,000 | 670 | 2,700 | 780 | 3,800 | 3,600 | 2,550 | 400 | 650 |

[1] Performing sector

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources 1987* (forthcoming)

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## Appendix table 4-6. National R&D expenditures, by character of work: 1960-87

| Year | Basic research | Applied research | Development | Basic research | Applied research | Development |
|---|---|---|---|---|---|---|
| | Millions of dollars | | | Millions of constant 1982 dollars[1] | | |
| 1960 | $1,197 | $3,020 | $9,306 | 3,868 | 9,758 | 30,068 |
| 1961 | 1,401 | 3,065 | 9,850 | 4,485 | 9,811 | 31,530 |
| 1962 | 1,724 | 3,665 | 10,005 | 5,398 | 11,475 | 31,324 |
| 1963 | 1,965 | 3,742 | 11,352 | 6,065 | 11,549 | 35,037 |
| 1964 | 2,289 | 4,128 | 12,437 | 6,951 | 12,536 | 37,768 |
| 1965 | 2,555 | 4,339 | 13,150 | 7,564 | 12,845 | 38,928 |
| 1966 | 2,814 | 4,601 | 14,431 | 8,049 | 13,161 | 41,279 |
| 1967 | 3,056 | 4,786 | 15,310 | 8,503 | 13 300 | 42,599 |
| 1968 | 3,296 | 5,131 | 16,178 | 8,736 | 13,599 | 42,878 |
| 1969 | 3,441 | 5,316 | 16,874 | 8,650 | 13,383 | 42,418 |
| 1970 | 3,549 | 5,720 | 16,865 | 8,444 | 13,609 | 40,126 |
| 1971 | 3,672 | 5,739 | 17,265 | 8,274 | 12,932 | 38,903 |
| 1972 | 3,829 | 5,984 | 18,664 | 8,236 | 12,872 | 40,146 |
| 1973 | 3,946 | 6,597 | 20,175 | 7,965 | 13,317 | 40,725 |
| 1974 | 4,239 | 7,228 | 21,397 | 7,956 | 13,395 | 39,653 |
| 1975 | 4,608 | 7,863 | 22,742 | 7,769 | 13,257 | 38,344 |
| 1976 | 4,977 | 9,046 | 24,995 | 7,891 | 14,343 | 39,631 |
| 1977 | 5,537 | 9,745 | 27,501 | 8,230 | 14,484 | 40,875 |
| 1978 | 6,392 | 10,844 | 30,893 | 8,851 | 15,015 | 42,776 |
| 1979 | 7,257 | 12,372 | 35,304 | 9,236 | 15,746 | 44,933 |
| 1980 | 8,079 | 14,050 | 40,464 | 9,425 | 16,391 | 47,205 |
| 1981 | 9,180 | 16,877 | 45,783 | 9,770 | 17,962 | 48,726 |
| 1982 | 9,937 | 18,518 | 50,861 | 9,937 | 18,518 | 50,861 |
| 1983 | 11,058 | 20,351 | 55,795 | 10,647 | 19,595 | 53,721 |
| 1984 | 12,076 | 21,445 | 64,118 | 11,210 | 19,906 | 59,517 |
| 1985 (Prelim.) | 13,222 | 23,324 | 70,916 | 11,893 | 20,980 | 63,791 |
| 1986(Est.) | 14,309 | 25,020 | 77,464 | 12,546 | 21,938 | 67,921 |
| 1987(Est.) | 14,815 | 26,095 | 83,340 | 12,570 | 22,141 | 70,711 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: The National Science Foundation uses the following definitions of character of work in its resource surveys.

Basic research - Basic research has as its objective "a fuller knowledge or understanding of the subject under study, rather than a practical application thereof. To take into account industrial goals NSF modifies this definition for the industry sector to indicate that basic research advances scientific knowledge not having specific commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company."

Applied research - Applied research is directed toward gaining "knowledge or understanding necessary for determining the means by which a recognized and specific need n :y be met." In industry applied research includes investigations directed "to the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes."

Development - Development is the "systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices systems or methods, including design and development or prototypes and processes."

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

See figure O-5 in Overview.

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## Appendix table 4-7. National research and development expenditures, by sector and character of work: 1985

| Sector | Basic research | Applied research | Development |
|---|---|---|---|
| | Millions of dollars | | |
| Universities and colleges[1] | 6,377 | 2,572 | 555 |
| Non-profit institutions[1] | 1,063 | 869 | 633 |
| Federally funded research and development centers[2] | 1,221 | 1,777 | 3,063 |
| Federal government | 1,961 | 3,148 | 7,889 |
| Industry[1] | 2,600 | 14,958 | 58,776 |

[1] Excludes federally funded research and development centers.
[2] Includes university-administered, nonprofit-administered, and industry-administered FFRDCs

SOURCES: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming); NSF, *Federal Funds for Research and Development*, Vols 34 and 35; NSF, *Research and Development in Industry, 1985*

See figure O-23 in Overview.

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## Appendix table 4-8. Academic research and development and nonacademic basic research: 1960-87

| Year | Academic research and development | | | | Nonacademic basic research | | | |
|---|---|---|---|---|---|---|---|---|
| | Millions of | | As a percent of | | Millions of | | As a percent of | |
| | Current dollars | Constant 1982 dollars[1] | Total R&D | GNP | Current dollars | Constant 1982 dollars[1] | Total R&D | GNP |
| 1960 | 646 | 2,077 | 4.78 | 0.13 | 764 | 2,464 | 5.65 | 0.15 |
| 1961 | 763 | 2,427 | 5.33 | 0.14 | 865 | 2,762 | 6.04 | 0.16 |
| 1962 | 904 | 2,825 | 5.87 | 0.16 | 1,065 | 3,332 | 6.92 | 0.19 |
| 1963 | 1,081 | 3,318 | 6.34 | 0.18 | 1,151 | 3,546 | 6.75 | 0.19 |
| 1964 | 1,275 | 3,858 | 6.76 | 0.20 | 1,286 | 3,899 | 6.82 | 0.20 |
| 1965 | 1,474 | 4,367 | 7.35 | 0.21 | 1,417 | 4,196 | 7.07 | 0.20 |
| 1966 | 1,715 | 4,937 | 7.85 | 0.22 | 1,511 | 4,333 | 6.92 | 0.20 |
| 1967 | 1,921 | 5,347 | 8.30 | 0.24 | 1,599 | 4,450 | 6.91 | 0.20 |
| 1968 | 2,149 | 5,778 | 8.73 | 0.24 | 1,647 | 4,392 | 6.69 | 0.18 |
| 1969 | 2,225 | 5,676 | 8.68 | 0.23 | 1,730 | 4,379 | 6.75 | 0.18 |
| 1970 | 2,335 | 5,629 | 8.93 | 0.23 | 1,753 | 4,197 | 6.71 | 0.17 |
| 1971 | 2,500 | 5,726 | 9.37 | 0.23 | 1,758 | 3,993 | 6.59 | 0.16 |
| 1972 | 2,630 | 5,710 | 9.24 | 0.2[illegible] | 1,807 | 3,904 | 6.35 | 0.15 |
| 1973 | 2,884 | 5,965 | 9.39 | 0.21 | 1,893 | 3,866 | 6.16 | 0.14 |
| 1974 | 3,023 | 5,796 | 9.20 | 0.21 | 2,085 | 3,926 | 6.34 | 0.14 |
| 1975 | 3,409 | 5,927 | 9.68 | 0.21 | 2,198 | 3,761 | 6.24 | 0.14 |
| 1976 | 3,729 | 6,007 | 9.56 | 0.21 | 2,428 | 3,879 | 6.22 | 0.14 |
| 1977 | 4,067 | 6,067 | 9.51 | 0.20 | 2,737 | 4,076 | 6.40 | 0.14 |
| 1978 | 4,625 | 6,449 | 9.61 | 0.21 | 3,216 | 4,469 | 6.68 | 0.14 |
| 1979 | 5,361 | 6,882 | 9.76 | 0.21 | 3,645 | 4,659 | 6.64 | 0.15 |
| 1980 | 6,060 | 7,151 | 9.68 | 0.22 | 4,053 | 4,755 | 6.48 | 0.15 |
| 1981 | 6,819 | 7,316 | 9.49 | 0.22 | 4,604 | 4,919 | 6.41 | 0.15 |
| 1982 | 7,276 | 7,276 | 9.17 | 0.23 | 5,080 | 5,080 | 6.40 | 0.16 |
| 1983 | 7,807 | 7,490 | 8.95 | 0.23 | 5,789 | 5,565 | 6.64 | 0.17 |
| 1984 | 8,503 | 7,859 | 8.71 | 0.23 | 6,438 | 5,965 | 6.59 | 0.17 |
| 1985 | 9,504 | 8,509 | 8.84 | 0.24 | 6,845 | 6,144 | 6.37 | 0.17 |
| 1986 (Est.) | 10,600 | 9,229 | 9.08 | 0.25 | 7,209 | 6,302 | 6.17 | 0.17 |
| 1987 (Est.) | 11,150 | 9,439 | 8.97 | 0.25 | 7,445 | 6,311 | 5.99 | 0.17 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming), and unpublished data

See figure 4-1.

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## Appendix table 4-9. Nonacademic applied research: 1960-87

| Year | Nonacademic[1] applied research: Current dollars | Nonacademic[1] applied research: Constant[2] dollars | Research and development: Current dollars | Research and development: Constant[2] dollars | Nonacademic applied research as a percent of R&D: Percent |
|---|---|---|---|---|---|
| | Millions of dollars | | | | |
| 1960 | $2,841 | $9,168 | $13,523 | $43,648 | 21.0 |
| 1961 | 2,873 | 9,181 | 14,316 | 45,764 | 20.1 |
| 1962 | 3,460 | 10,827 | 15,394 | 48,176 | 22.5 |
| 1963 | 3,515 | 10,833 | 17,059 | 52,585 | 20.6 |
| 1964 | 3,896 | 11,819 | 18,854 | 57,202 | 20.7 |
| 1965 | 4,060 | 12,022 | 20,044 | 59,351 | 20.3 |
| 1966 | 4,273 | 12,245 | 21,846 | 62,589 | 19.6 |
| 1967 | 4,406 | 12,260 | 23,146 | 64,406 | 19.0 |
| 1968 | 4,727 | 12,580 | 24,605 | 65,458 | 19.2 |
| 1969 | 4,909 | 12,390 | 25,631 | 64,672 | 19.2 |
| 1970 | 5,293 | 12,642 | 26,134 | 62,405 | 20.3 |
| 1971 | 5,265 | 11,919 | 26,676 | 60,385 | 19.7 |
| 1972 | 5,460 | 11,776 | 28,477 | 61,414 | 19.2 |
| 1973 | 5,884 | 11,962 | 30,718 | 62,427 | 19.2 |
| 1974 | 6,492 | 12,146 | 32,864 | 61,467 | 19.8 |
| 1975 | 7,012 | 11,928 | 35,213 | 59,883 | 19.9 |
| 1976 | 8,030 | 12,793 | 39,018 | 62,134 | 20.6 |
| 1977 | 8,678 | 12,912 | 42,783 | 63,653 | 20.3 |
| 1978 | 9,631 | 13,362 | 48,129 | 66,769 | 20.0 |
| 1979 | 10,907 | 13,914 | 54,933 | 70,077 | 19.9 |
| 1980 | 12,359 | 14,460 | 62,593 | 73,235 | 19.7 |
| 1981 | 15,011 | 16,006 | 71,840 | 76,610 | 20.9 |
| 1982 | 16,514 | 16,514 | 79,316 | 79,316 | 20.8 |
| 1983 | 18,250 | 17,558 | 87,20[illegible] | 83,891 | 20.9 |
| 1984 | 19,055 | 17,673 | 97,639 | 90,542 | 19.5 |
| 1985 | 20,752 | 18,649 | 107,462 | 96,556 | 19.3 |
| 1986 (Est.) | 22,120 | 19,370 | 116,793 | 102,236 | 18.9 |
| 1987 (Est.) | 23,015 | 19,519 | 124,250 | 105,364 | 18.5 |

[1] National expenditures for applied research minus applied research funds spent at universities and colleges

[2] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

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## Appendix table 4-10. Sources of support for academic research and development: 1960-87

| Fiscal year | Total | Federal government | State & local governments | Industry | Institutional funds | All other sources |
|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | |
| 1960 | 646 | 405 | 85 | 40 | 64 | 52 |
| 1961 | 763 | 500 | 95 | 40 | 70 | 58 |
| 1962 | 904 | 613 | 106 | 40 | 79 | 66 |
| 1963 | 1,081 | 760 | 118 | 41 | 89 | 73 |
| 1964 | 1,275 | 917 | 132 | 40 | 103 | 83 |
| 1965 | 1,474 | 1,073 | 143 | 41 | 124 | 93 |
| 1966 | 1,715 | 1,261 | 156 | 42 | 148 | 108 |
| 1967 | 1,921 | 1,409 | 164 | 48 | 181 | 119 |
| 1968 | 2,149 | 1,572 | 172 | 55 | 218 | 132 |
| 1969 | 2,225 | 1,600 | 197 | 60 | 223 | 145 |
| 1970 | 2,335 | 1,647 | 219 | 61 | 243 | 165 |
| 1971 | 2,500 | 1,724 | 255 | 70 | 274 | 177 |
| 1972 | 2,630 | 1,795 | 269 | 74 | 305 | 187 |
| 1973 | 2,884 | 1,985 | 295 | 84 | 318 | 202 |
| 1974 | 3,022 | 2,032 | 308 | 95 | 368 | 219 |
| 1975 | 3,409 | 2,288 | 332 | 113 | 417 | 259 |
| 1976 | 3,729 | 2,512 | 364 | 123 | 446 | 285 |
| 1977 | 4,067 | 2,726 | 374 | 139 | 514 | 314 |
| 1978[1] | 4,625 | 3,059 | 414 | 170 | 623 | 359 |
| 1979 | 5,361 | 3,595 | 470 | 194 | 728 | 374 |
| 1980 | 6,061 | 4,097 | 491 | 237 | 827 | 408 |
| 1981 | 6,810 | 4,557 | 544 | 291 | 972 | 445 |
| 1982 | 7,266 | 4,747 | 609 | 333 | 1,078 | 499 |
| 1983 | 7,798 | 4,953 | 624 | 378 | 1,256 | 587 |
| 1984 | 8,508 | 5,386 | 683 | 461 | 1,350 | 629 |
| 1985 | 9,524 | 5,998 | 729 | 543 | 1,557 | 698 |
| 1986 | 10,718 | 6,633 | 903 | 667 | 1,774 | 740 |
| 1987 (est.) | 11,150 | 7,000 | NA | 670 | NA | NA |
| | Millions constant 1982 dollars[2] | | | | | |
| 1960 | 2,087 | 1,309 | 275 | 129 | 207 | 168 |
| 1961 | 2,442 | 1,601 | 304 | 128 | 224 | 186 |
| 1962 | 2,830 | 1,919 | 332 | 125 | 247 | 207 |
| 1963 | 3,336 | 2,346 | 364 | 127 | 275 | 225 |
| 1964 | 3,872 | 2,785 | 401 | 121 | 313 | 252 |
| 1965 | 4,364 | 3,176 | 423 | 121 | 367 | 275 |
| 1966 | 4,906 | 3,607 | 446 | 120 | 423 | 309 |
| 1967 | 5,345 | 3,920 | 456 | 134 | 504 | 331 |
| 1968 | 5,696 | 4,166 | 456 | 146 | 578 | 350 |
| 1969 | 5,593 | 4,022 | 495 | 151 | 561 | 365 |
| 1970 | 5,556 | 3,919 | 521 | 145 | 578 | 393 |
| 1971 | 5,633 | 3,885 | 575 | 158 | 617 | 399 |
| 1972 | 5,657 | 3,861 | 579 | 159 | 656 | 402 |
| 1973 | 5,822 | 4,007 | 595 | 170 | 642 | 408 |
| 1974 | 5,600 | 3,766 | 571 | 176 | 682 | 406 |
| 1975 | 5,748 | 3,858 | 560 | 191 | 703 | 437 |
| 1976 | 5,912 | 3,983 | 577 | 195 | 707 | 452 |
| 1977 | 6,045 | 4,052 | 556 | 207 | 764 | 467 |
| 1978[1] | 6,404 | 4,236 | 573 | 235 | 863 | 497 |
| 1979 | 6,823 | 4,576 | 598 | 247 | 927 | 476 |
| 1980 | 7,071 | 4,780 | 573 | 276 | 965 | 476 |
| 1981 | 7,248 | 4,850 | 579 | 310 | 1,034 | 474 |
| 1982 | 7,266 | 4,747 | 609 | 333 | 1,078 | 499 |
| 1983 | 7,508 | 4,769 | 601 | 364 | 1,209 | 565 |
| 1984 | 7,898 | 5,000 | 634 | 428 | 1,253 | 584 |
| 1985 | 8,567 | 5,395 | 656 | 488 | 1,401 | 628 |
| 1986 | 9,398 | 5,816 | 792 | 585 | 1,555 | 649 |
| 1987 (est.) | 9,460 | 5,939 | NA | 568 | NA | NA |

(continued)

**Appendix table 4-10. (Continued)**

| | As a percent of total academic R&D | | | | | |
|---|---|---|---|---|---|---|
| 1960 | 100.0 | 62.7 | 13.2 | 6.2 | 9.9 | 8.0 |
| 1961 | 100.0 | 65.5 | 12.5 | 5.2 | 9.2 | 7.6 |
| 1962 | 100.0 | 67.8 | 11.7 | 4.4 | 8.7 | 7.3 |
| 1963 | 100.0 | 70.3 | 10.9 | 3.8 | 8.2 | 6.8 |
| 1964 | 100.0 | 71.9 | 10.4 | 3.1 | 8.1 | 6.5 |
| 1965 | 100.0 | 72.8 | 9.7 | 2.8 | 8.4 | 6.3 |
| 1966 | 100.0 | 73.5 | 9.1 | 2.4 | 8.6 | 6.3 |
| 1967 | 100.0 | 73.3 | 8.5 | 2.5 | 9.4 | 6.2 |
| 1968 | 100.0 | 73.2 | 8.0 | 2.6 | 10.1 | 6.1 |
| 1969 | 100.0 | 71.9 | 8.9 | 2.7 | 10.0 | 6.5 |
| 1970 | 100.0 | 70.5 | 9.4 | 2.6 | 10.4 | 7.1 |
| 1971 | 100.0 | 69.0 | 10.2 | 2.8 | 11.0 | 7.1 |
| 1972 | 100.0 | 68.3 | 10.2 | 2.8 | 11.6 | 7.1 |
| 1973 | 100.0 | 68.8 | 10.2 | 2.9 | 11.0 | 7.0 |
| 1974 | 100.0 | 67.2 | 10.2 | 3.1 | 12.2 | 7.2 |
| 1975 | 100.0 | 67.1 | 9.7 | 3.3 | 12.2 | 7.6 |
| 1976 | 100.0 | 67.4 | 9.8 | 3.3 | 12.0 | 7.6 |
| 1977 | 100.0 | 67.0 | 9.2 | 3.4 | 12.6 | 7.7 |
| 1978[1] | 100.0 | 66.1 | 9.0 | 3.7 | 13.5 | 7.8 |
| 1979 | 100.0 | 67.1 | 8.8 | 3.6 | 13.6 | 7.0 |
| 1980 | 100.0 | 67.6 | 8.1 | 3.9 | 13.6 | 6.7 |
| 1981 | 100.0 | 66.9 | 8.0 | 4.3 | 14.3 | 6.5 |
| 1982 | 100.0 | 65.3 | 8.4 | 4.6 | 14.8 | 6.9 |
| 1983 | 100.0 | 63.5 | 8.0 | 4.8 | 16.1 | 7.5 |
| 1984 | 100.0 | 63.3 | 8.0 | 5.4 | 15.9 | 7.4 |
| 1985 | 100.0 | 63.0 | 7.7 | 5.7 | 16.3 | 7.3 |
| 1986 | 100.0 | 61.9 | 8.4 | 6.2 | 16.6 | 6.9 |
| 1987 (est.) | 100.0 | 62.8 | NA | 6.0 | NA | NA |

[1] Estimated, based on data collected from doctorate-granting institutions only.
[2] GNP deflator used to convert current to constant dollars.

SOURCE: National Science Foundation. *Academic Science and Engineering, R&D Funds, FY 1986.* and unpublished data

See figure O-31 in Overview

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## Appendix table 4-11. Federal obligations for academic research and development, by agency: 1967-87

| Year | All agencies | Total agencies | DOE[1] | DOD | NIH | NASA | NSF | USDA | Other agencies |
|---|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | | |
| 1967 | $1,454 | $1,240 | $90 | $280 | $478 | $119 | $209 | $64 | $214 |
| 1968 | 1,487 | 1,252 | 93 | 244 | 525 | 108 | 221 | 61 | 235 |
| 1969 | 1,529 | 1,273 | 101 | 263 | 535 | 99 | 213 | 62 | 256 |
| 1970 | 1,476 | 1,238 | 100 | 216 | 518 | 111 | 228 | 65 | 238 |
| 1971 | 1,645 | 1,366 | 94 | 211 | 603 | 119 | 267 | 72 | 279 |
| 1972 | 1,904 | 1,641 | 85 | 217 | 756 | 134 | 362 | 87 | 263 |
| 1973 | 1,917 | 1,647 | 83 | 204 | 761 | 131 | 374 | 94 | 270 |
| 1974 | 2,214 | 1,927 | 94 | 197 | 1,027 | 125 | 389 | 95 | 287 |
| 1975 | 2,411 | 2,086 | 132 | 203 | 1,077 | 131 | 435 | 108 | 325 |
| 1976 | 2,552 | 2,251 | 145 | 240 | 1,185 | 124 | 437 | 120 | 301 |
| 1977 | 2,905 | 2,541 | 188 | 273 | 1,311 | 118 | 511 | 140 | 364 |
| 1978 | 3,375 | 2,966 | 240 | 383 | 1,493 | 127 | 537 | 186 | 409 |
| 1979 | 3,889 | 3,419 | 260 | 438 | 1,765 | 139 | 617 | 200 | 470 |
| 1980 | 4,263 | 3,727 | 285 | 495 | 1,888 | 158 | 685 | 216 | 536 |
| 1981 | 4,466 | 3,973 | 300 | 573 | 1,984 | 171 | 702 | 243 | 493 |
| 1982 | 4,605 | 4,123 | 277 | 664 | 2,026 | 186 | 715 | 255 | 482 |
| 1983 | 4,966 | 4,532 | 297 | 724 | 2,264 | 189 | 783 | 275 | 434 |
| 1984 | 5,565 | 5,074 | 321 | 830 | 2,560 | 222 | 880 | 261 | 491 |
| 1985 | 6,299 | 5,765 | 357 | 940 | 2,918 | 255 | 1,002 | 293 | 534 |
| 1986 (Est.) | 6,555 | 6,001 | 328 | 1,074 | 3,033 | 305 | 994 | 267 | 554 |
| 1987 (Est.) | 6,559 | 6,097 | 315 | 1,232 | 2,846 | 325 | 1,143 | 236 | 462 |
| | Millions constant 1982 dollars[2] | | | | | | | | |
| 1967 | 4,048 | 3,451 | 250 | 779 | 1,330 | 331 | 582 | 178 | 596 |
| 1968 | 3,998 | 3,366 | 250 | 656 | 1,412 | 290 | 594 | 164 | 632 |
| 1969 | 3,901 | 3,247 | 258 | 671 | 1,365 | 253 | 543 | 158 | 653 |
| 1970 | 3,558 | 2,985 | 241 | 521 | 1,249 | 268 | 550 | 157 | 574 |
| 1971 | 3,768 | 3,129 | 215 | 483 | 1,381 | 273 | 612 | 165 | 639 |
| 1972 | 4,134 | 3,563 | 185 | 471 | 1,641 | 291 | 786 | 189 | 571 |
| 1973 | 3,965 | 3,406 | 172 | 422 | 1,574 | 271 | 774 | 194 | 558 |
| 1974 | 4,245 | 3,694 | 180 | 378 | 1,969 | 240 | 746 | 182 | 550 |
| 1975 | 4,192 | 3,627 | 229 | 353 | 1,872 | 228 | 756 | 188 | 565 |
| 1976 | 4,111 | 3,626 | 234 | 387 | 1,909 | 200 | 704 | 193 | 485 |
| 1977 | 4,334 | 3,791 | 280 | 407 | 1,956 | 176 | 762 | 209 | 543 |
| 1978 | 4,706 | 4,136 | 335 | 534 | 2,082 | 177 | 749 | 259 | 570 |
| 1979 | 4,992 | 4,389 | 334 | 562 | 2,266 | 178 | 792 | 257 | 603 |
| 1980 | 5,031 | 4,398 | 336 | 584 | 2,228 | 186 | 808 | 255 | 633 |
| 1981 | 4,791 | 4,262 | 322 | 615 | 2,129 | 183 | 753 | 261 | 529 |
| 1982 | 4,605 | 4,123 | 277 | 664 | 2,026 | 186 | 715 | 255 | 482 |
| 1983 | 4,764 | 4,348 | 285 | 695 | 2,172 | 181 | 751 | 264 | 416 |
| 1984 | 5,144 | 4,690 | 297 | 767 | 2,366 | 205 | 813 | 241 | 454 |
| 1985 | 5,640 | 5,162 | 320 | 842 | 2,613 | 228 | 897 | 262 | 478 |
| 1986 (Est.) | 5,707 | 5,225 | 286 | 935 | 2,641 | 266 | 865 | 232 | 482 |
| 1987 (Est.) | 5,552 | 5,161 | 267 | 1,043 | 2,409 | 275 | 968 | 200 | 391 |

[1] Atomic Energy Commission, 1967-73, Energy Research and Development Administration, 1974-76, Department of Energy 1977-87.

[2] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research and Development. Detailed Historical Tables, FY 1955-87*

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**Appendix table 4-12. Forms of Federal support for academic science and engineering, and NIH indirect cost ratio: 1966-86**

| | Research & development plant | Fellowships, traineeships & training grants | General support for s/e | Other s/e activities | Research & development | NIH Indirect cost ratio[1] |
|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | (Percent) |
| 1966 | 114,767 | 365,560 | ([2]) | 431,031 | 1,252,146 | 15.3 |
| 1967 | 111,309 | 447,236 | ([2]) | 464,008 | 1,301,242 | 16.9 |
| 1968 | 96,148 | 440,895 | ([2]) | 414,469 | 1,398,305 | 19.1 |
| 1969 | 54,516 | 436,270 | ([2]) | 395,932 | 1,474,681 | 20.9 |
| 1970 | 44,778 | 429,408 | ([2]) | 266,775 | 1,446,618 | 22.2 |
| 1971 | 29,942 | 421,029 | 99,669 | 212,369 | 1,551,391 | 22.6 |
| 1972 | 36,917 | 387,888 | 83,288 | 211,592 | 1,852,963 | 20.6 |
| 1973 | 43,338 | 287,210 | 38,964 | 210,788 | 1,870,690 | 23.2 |
| 1974 | 29,009 | 326,600 | 86,974 | 205,691 | 2,085,204 | 24.4 |
| 1975 | 44,787 | 201,273 | 46,353 | 262,256 | 2,246,088 | 25.9 |
| 1976 | 23,899 | 174,871 | 74,483 | 252,223 | 2,430,970 | 26.7 |
| 1977 | 36,471 | 184,671 | 75,928 | 247,968 | 2,803,017 | 27.2 |
| 1978 | 34,328 | 205,925 | 74,398 | 254,505 | 3,385,770 | 27.2 |
| 1979 | 32,068 | 204,866 | 92,483 | 262,985 | 3,873,514 | 27.8 |
| 1980 | 37,780 | 210,121 | 91,541 | 287,211 | 4,159,857 | 28.6 |
| 1981 | 27,694 | 205,448 | 92,721 | 321,499 | 4,410,199 | 29.5 |
| 1982 | 31,200 | 176,582 | 80,137 | 336,387 | 4,553,755 | 30.0 |
| 1983 | 37,547 | 189,616 | 94,847 | 331,769 | 5,023,677 | 30.5 |
| 1984 | 49,764 | 194,895 | 112,588 | 396,432 | 5,634,400 | 31.2[3] |
| 1985 | 113,932 | 253,082 | 119,171 | 389,746 | 6,368,608 | 31.7[3] |
| 1986 | 105,827 | 246,196 | 111,130 | 392,698 | 6,538,280 | NA |

[1] The indirect cost rate is the percent of total grant support which goes to indirect costs of research. The NIH ratio is used here as a proxy for all Federal research. Other estimates are lower See, for example, General Accounting Office, "University Finances. Research Revenues and Expenditures, GAO/RCED-86-162BR, July 1986, which estimates the all-agency indirect cost rate in 1984 at 25 percent (p. 30)

[2] Not separately classified, included under other science/engineering activities.

[3] Projected.

SOURCES: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1985*, National Institutes of Health Federal Assistance Accounting Branch

See figure 4-2.

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## Appendix table 4-13. Sources of support for nonacademic[1] basic research: 1960-87

| Year | Total | Federal Government | Industry | Other Nonprofit institutions |
|---|---|---|---|---|
| | Millions of dollars | | | |
| 1960 | $ 764 | $ 416 | $ 318 | $30 |
| 1961 | 865 | 492 | 336 | 37 |
| 1962 | 1,065 | 650 | 369 | 46 |
| 1963 | 1,151 | 701 | 400 | 50 |
| 1964 | 1,286 | 830 | 409 | 47 |
| 1965 | 1,417 | 930 | 435 | 52 |
| 1966 | 1,511 | 970 | 483 | 58 |
| 1967 | 1,599 | ,077 | 461 | 61 |
| 1968 | 1,647 | 1,085 | 499 | 63 |
| 1969 | 1,730 | 1,162 | 501 | 67 |
| 1970 | 1,753 | 1,193 | 488 | 72 |
| 1971 | 1,758 | 1,180 | 501 | 77 |
| 1972 | 1,607 | 1,213 | 510 | 84 |
| 1973 | 1,893 | 1,255 | 548 | 90 |
| 1974 | 2,085 | 1,389 | 590 | 106 |
| 1975 | 2,198 | 1,445 | 633 | 120 |
| 1976 | 2,428 | 1,595 | 698 | 135 |
| 1977 | 2,737 | 1,816 | 771 | 150 |
| 1978 | 3,216 | 2,181 | 865 | 170 |
| 1979 | 3,645 | 2,472 | 978 | 195 |
| 1980 | 4,053 | 2,708 | 1,130 | 215 |
| 1981 | 4,604 | 2,961 | 1,418 | 225 |
| 1982 | 5,090 | 3,250 | 1,615 | 215 |
| 1983 | 5,789 | 3,737 | 1,832 | 220 |
| 1984 | 6,438 | 4,110 | 2,103 | 225 |
| 1985 | 6,845 | 4,359 | 2,256 | 230 |
| 1986 (Est.) | 7,209 | 4,570 | 2,399 | 240 |
| 1987 (Est.) | 7,445 | 4,665 | 2,530 | 250 |
| | Millions constant 1982 dollars[2] | | | |
| 1960 | $2,468 | $1,344 | $1,027 | $97 |
| 1961 | 2,769 | 1,575 | 1,076 | 118 |
| 1962 | 3,334 | 2,035 | 1,155 | 144 |
| 1963 | 3,552 | 2,164 | 1,235 | 154 |
| 1964 | 3,905 | 2,520 | 1,242 | 143 |
| 1965 | 4,195 | 2,753 | 1,288 | 154 |
| 1966 | 4,322 | 2,775 | 1,382 | 166 |
| 1967 | 4,449 | 2,997 | 1,283 | 170 |
| 1968 | 4,365 | 2,876 | 1,323 | 167 |
| 1969 | 4,349 | 2,921 | 1,259 | 168 |
| 1970 | 4,171 | 2,838 | 1,161 | 171 |
| 1971 | 3,961 | 2,659 | 1,129 | 174 |
| 1972 | 3,887 | 2,609 | 1,097 | 181 |
| 1973 | 3,821 | 2,533 | 1,106 | 182 |
| 1974 | 3,864 | 2,574 | 1,093 | 196 |
| 1975 | 3,706 | 2,436 | 1,067 | 202 |
| 1976 | 3,850 | 2,529 | 1,107 | 214 |
| 1977 | 4,068 | 2,699 | 1,146 | 223 |
| 1978 | 4,453 | 3,020 | 1,198 | 235 |
| 1979 | 4,639 | 3,146 | 1,245 | 248 |
| 1980 | 4,728 | 3,159 | 1,318 | 251 |
| 1981 | 4,900 | 3,151 | 1,509 | 239 |
| 1982 | 5,090 | 3,250 | 1,615 | 215 |
| 1983 | 5,574 | 3,598 | 1,764 | 212 |
| 1984 | 5,976 | 3,815 | 1,952 | 209 |
| 1985 | 6,157 | 3,921 | 2,029 | 207 |
| 1986 (Est.) | 6,321 | 4,007 | 2,103 | 210 |
| 1987 (Est.) | 6,317 | 3,958 | 2,147 | 212 |

[1] Expenditures for basic research minus basic research funds sent to universities and colleges
[2] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources. 1987* (forthcoming)

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## Appendix table 4-14. Federal obligations for basic research at FFRDC's, by agency: 1967-88

| Year | All agencies | DOE[1] | DOD | NIH | NASA | NSF | All other agencies |
|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | |
| 1967 | $242 | $207 | $2 | $0 | $14 | $17 | $2 |
| 1968 | 258 | 202 | 4 | 0 | 28 | 21 | 2 |
| 1969 | 253 | 199 | 4 | 0 | 21 | 25 | 3 |
| 1970 | 270 | 203 | 2 | 0 | 39 | 24 | 2 |
| 1971 | 259 | 200 | 0 | 0 | 27 | 30 | 1 |
| 1972 | 294 | 201 | 1 | 1 | 49 | 42 | 0 |
| 1973 | 272 | 213 | 1 | 1 | 23 | 34 | 0 |
| 1974 | 261 | 209 | 5 | 2 | 4 | 40 | 1 |
| 1975 | 319 | 255 | 2 | 10 | 12 | 40 | 1 |
| 1976 | 353 | 276 | 1 | 19 | 9 | 45 | 1 |
| 1977 | 383 | 316 | 1 | 8 | 10 | 46 | 0 |
| 1978 | 428 | 345 | 2 | 16 | 9 | 55 | 0 |
| 1979 | 467 | 358 | 10 | 18 | 12 | 69 | 0 |
| 1980 | 515 | 395 | 25 | 18 | 16 | 61 | 0 |
| 1981 | 572 | 437 | 31 | 19 | 12 | 73 | 0 |
| 1982 | 613 | 491 | 6 | 23 | 19 | 74 | 0 |
| 1983 | 682 | 558 | 11 | 19 | 18 | 76 | 0 |
| 1984 | 752 | 607 | 14 | 20 | 19 | 91 | 0 |
| 1985 | 823 | 672 | 13 | 21 | 24 | 87 | 6 |
| 1986 | 822 | 675 | 11 | 26 | 22 | 83 | 4 |
| 1987 (Est.) | 912 | 744 | 15 | 32 | 24 | 92 | 4 |
| 1988 (Est.) | 987 | 814 | 7 | 28 | 35 | 99 | 4 |
| | As a percent of all agencies | | | | | | |
| 1967 | 100.0 | 85.6 | 0.9 | 0.0 | 5.7 | 7.0 | 0.9 |
| 1968 | 100.0 | 78.3 | 1.5 | 0.1 | 10.8 | 8.3 | 0.9 |
| 1969 | 100.0 | 78.8 | 1.8 | 0.0 | 8.5 | 9.7 | 1.2 |
| 1970 | 100.0 | 75.2 | 0.7 | 0.1 | 14.5 | 8.9 | 0.6 |
| 1971 | 100.0 | 77.3 | 0.2 | 0.2 | 10.6 | 11.6 | 0.2 |
| 1972 | 100.0 | 68.2 | 0.2 | 0.3 | 16.8 | 14.5 | 0.0 |
| 1973 | 100.0 | 78.4 | 0.5 | 0.3 | 8.3 | 12.5 | 0.0 |
| 1974 | 100.0 | 80.2 | 1.9 | 0.7 | 1.4 | 15.3 | 0.4 |
| 1975 | 100.0 | 79.8 | 0.5 | 3.1 | 3.8 | 12.4 | 0.3 |
| 1976 | 100.0 | 78.3 | 0.4 | 5.5 | 2.7 | 12.7 | 0.4 |
| 1977 | 100.0 | 82.7 | 0.3 | 2.2 | 2.6 | 12.1 | 0.1 |
| 1978 | 100.0 | 80.6 | 0.4 | 3.7 | 2.2 | 13.0 | 0.1 |
| 1979 | 100.0 | 76.6 | 2.1 | 3.9 | 2.6 | 14.8 | 0.0 |
| 1980 | 100.0 | 76.8 | 4.9 | 3.4 | 3.1 | 11.8 | 0.0 |
| 1981 | 100.0 | 76.4 | 5.5 | 3.2 | 2.2 | 12.7 | 0.0 |
| 1982 | 100.0 | 80.1 | 0.9 | 3.7 | 3.1 | 12.1 | 0.0 |
| 1983 | 100.0 | 81.9 | 1.6 | 2.7 | 2.6 | 11.1 | 0.1 |
| 1984 | 100.0 | 80.7 | 1.8 | 2.7 | 2.6 | 12.2 | 0.0 |
| 1985 | 100.0 | 81.6 | 1.6 | 2.6 | 2.9 | 10.5 | 0.7 |
| 1986 | 100.0 | 82.2 | 1.3 | 3.2 | 2.7 | 10.1 | 0.5 |
| 1987 (Est.) | 100.0 | 81.6 | 1.7 | 3.5 | 2.7 | 10.1 | 0.5 |
| 1988 (Est.) | 100.0 | 82.5 | 0.7 | 2.8 | 3.6 | 10.0 | 0.4 |

[1] Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 1974-1976; Department of Energy, 1977-present.

SOURCES: National Science Foundation, *Federal Funds for Research and Development: FY 1986, 1987, and 1988*, Vol. XXXVI; National Science Foundation, *Federal Funds for Research and Development: Detailed Historical Tables: FY 1955-1987*

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## Appendix table 4-15. Federal obligations for basic research to intramural performers, by agency: 1967-87

| Year | All agencies | DOE[1] | DOD | NIH | NASA | NSF | USDA | All other agencies |
|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | |
| 1967 ........ | $435 | $5 | $82 | $65 | $110 | $11 | $63 | $99 |
| 1968 ........ | 432 | 2 | 86 | 75 | 88 | 11 | 67 | 103 |
| 1969 ........ | 532 | 2 | 90 | 85 | 153 | 14 | 77 | 111 |
| 1970 ........ | 558 | 1 | 148 | 88 | 134 | 11 | 85 | 91 |
| 1971 ........ | 565 | 1 | 141 | 107 | 128 | 14 | 87 | 87 |
| 1972 ........ | 597 | 1 | 153 | 120 | 133 | 14 | 97 | 79 |
| 1973 ........ | 608 | 1 | 144 | 125 | 141 | 8 | 100 | 89 |
| 1974 ........ | 696 | 2 | 145 | 149 | 164 | 46 | 103 | 87 |
| 1975 ........ | 734 | 0 | 143 | 164 | 173 | 38 | 107 | 109 |
| 1976 ........ | 786 | 0 | 162 | 187 | 147 | 58 | 120 | 112 |
| 1977 ........ | 914 | 1 | 166 | 204 | 192 | 75 | 144 | 132 |
| 1978 ........ | 1,029 | 7 | 164 | 245 | 221 | 77 | 161 | 154 |
| 1979 ........ | 1,089 | 5 | 183 | 281 | 221 | 57 | 169 | 173 |
| 1980 ........ | 1,182 | 6 | 199 | 320 | 225 | 68 | 180 | 184 |
| 1981 ........ | 1,302 | 6 | 226 | 335 | 216 | 99 | 202 | 218 |
| 1982 ........ | 1,466 | 7 | 246 | 405 | 251 | 112 | 219 | 226 |
| 1983 ........ | 1,690 | 18 | 276 | 449 | 305 | 126 | 239 | 277 |
| 1984 ........ | 1,861 | 11 | 303 | 479 | 345 | 130 | 274 | 319 |
| 1985 ........ | 1,961 | 21 | 301 | 543 | 318 | 138 | 296 | 344 |
| 1986 ........ | 2,018 | 25 | 308 | 579 | 363 | 126 | 293 | 323 |
| 1987 (Est) ... | 2,218 | 34 | 271 | 700 | 418 | 131 | 313 | 351 |
| 1988 (Est.) .. | 2,176 | 24 | 290 | 608 | 418 | 157 | 330 | 349 |
| | As a percent of all agencies | | | | | | | |
| 1967 ........ | 100.0 | 1.1 | 18.9 | 14.9 | 25.3 | 2.5 | 14.5 | 22.8 |
| 1968 ........ | 100.0 | 0.5 | 19.9 | 17.4 | 20.4 | 2.5 | 15.5 | 23.8 |
| 1969 ........ | 100.0 | 0.4 | 16.9 | 16.0 | 28.8 | 2.6 | 14.5 | 20.9 |
| 1970 ........ | 100.0 | 0.2 | 26.5 | 15.8 | 24.0 | 2.0 | 15.2 | 16.3 |
| 1971 ........ | 100.0 | 0.2 | 25.0 | 18.9 | 22.7 | 2.5 | 15.4 | 15.4 |
| 1972 ........ | 100.0 | 0.2 | 25.6 | 20.1 | 22.3 | 2.3 | 16.2 | 13.2 |
| 1973 ........ | [illegible] | 0.2 | 23.7 | 20.6 | 23.2 | 1.3 | 16.4 | 14.6 |
| 1974 ........ | 100.0 | 0.3 | 20.8 | 21.4 | 23.6 | 6.6 | 14.8 | 12.5 |
| 1975 ........ | 100.0 | 0.0 | 19.5 | 22.3 | 23.6 | 5.2 | 14.6 | 14.9 |
| 1976 ........ | 100.0 | 0.0 | 20.6 | 23.8 | 18.7 | 7.4 | 15.3 | 14.2 |
| 1977 ........ | 100.0 | 0.1 | 18.2 | 22.3 | 21.0 | 8.2 | 15.8 | 14.4 |
| 1978 ........ | 100.0 | 0.7 | 15.9 | 23.8 | 21.5 | 7.[illegible] | 15.6 | 15.0 |
| 1979 ........ | 100.0 | 0.5 | 16.8 | 25.8 | 20.3 | 5.2 | 15.5 | 15.9 |
| 1980 ........ | 100.0 | 0.5 | 16.8 | 27.1 | 19.0 | 5.8 | 15.2 | 15.6 |
| 1981 ........ | 100.0 | 0.5 | 17.4 | 25.7 | 16.6 | 7.6 | 15.5 | 16.7 |
| 1982 ........ | 100.0 | 0.5 | 16.8 | 27.6 | 17.1 | 7.6 | 14.9 | 15.4 |
| 1983 ........ | 100.0 | 1.1 | 16.3 | 26.6 | 18.0 | 7.5 | 14.1 | 16.4 |
| 1984 ........ | 100.0 | 0.6 | 16.3 | 25.7 | 18.5 | 7.0 | 14.7 | 17.1 |
| 1985 ........ | 100.0 | 1.1 | 15.3 | 27.7 | 16.2 | 7.0 | 15.1 | 17.5 |
| 1986 ........ | 100.0 | 1.2 | 15.3 | 28.7 | 18.0 | 6.2 | 14.5 | 16.0 |
| 1987 (Est) ... | 100.0 | 1.5 | 12.2 | 31.6 | 18.8 | 5.9 | 14.1 | 15.8 |
| 1988 (Est.) .. | 100.0 | 1.1 | 13.3 | 27.9 | 19.2 | 7.2 | 15.2 | 16.0 |

[1] Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 1974-1976, Department of Energy, 1977-present.

SOURCES: National Science Foundation, *Federal Funds for Research and Development. FY 1986, 1987, and 1988*, Vol. XXXVI; National Science Foundation, *Federal Funds for Research and Development Detailed Historical Tables: FY 1955-1987*

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## Appendix table 4-16. Expenditures for basic research in industry, by source of funds: 1960-87

| Year | Current dollars | | | Constant 1982 dollars[1] | | | Percent | |
|---|---|---|---|---|---|---|---|---|
| | Total | Federal | Nonfederal | Total | Federal | Nonfederal | Federal | Nonfederal |
| | Millions of dollars | | | | | | | |
| 1960 | $ 376 | $79 | $ 297 | $1,215 | $255 | $ 960 | 21.0% | 79.0% |
| 1961 | 395 | 81 | 314 | 1,264 | 259 | 1,005 | 20.5 | 79.5 |
| 1962 | 488 | 143 | 345 | 1,528 | 448 | 1,080 | 29.3 | 70.7 |
| 1963 | 522 | 147 | 375 | 1,611 | 454 | 1,157 | 28.2 | 71.8 |
| 1964 | 549 | 165 | 384 | 1,667 | 501 | 1,166 | 30.1 | 69.9 |
| 1965 | 592 | 186 | 406 | 1,753 | 551 | 1,202 | 31.4 | 68.6 |
| 1966 | 624 | 173 | 451 | 1,785 | 495 | 1,290 | 27.7 | 72.3 |
| 1967 | 629 | 202 | 427 | 1,750 | 562 | 1,188 | 32.1 | 67.9 |
| 1968 | 642 | 180 | 462 | 1,702 | 477 | 1,224 | 28.0 | 72.0 |
| 1969 | 618 | 160 | 458 | 1,554 | 402 | 1,151 | 25.9 | 74.1 |
| 1970 | 602 | 158 | 444 | 1,432 | 376 | 1,056 | 26.2 | 73.8 |
| 1971 | 590 | 134 | 456 | 1,329 | 302 | 1,027 | 22.7 | 77.3 |
| 1972 | 593 | 130 | 463 | 1,276 | 280 | 996 | 21.9 | 78.1 |
| 1973 | 631 | 132 | 499 | 1,274 | 266 | 1,007 | 20.9 | 79.1 |
| 1974 | 699 | 163 | 536 | 1,295 | 302 | 993 | 23.3 | 76.7 |
| 1975 | 730 | 157 | 573 | 1,231 | 265 | 966 | 21.5 | 78.5 |
| 1976 | 819 | 185 | 634 | 1,299 | 293 | 1,005 | 22.6 | 77.4 |
| 1977 | 911 | 210 | 701 | 1,354 | 312 | 1,042 | 23.1 | 76.9 |
| 1978 | 1,035 | 250 | 785 | 1,433 | 346 | 1,087 | 24.2 | 75.8 |
| 1979 | 1,158 | 265 | 893 | 1,474 | 337 | 1,137 | 22.9 | 77.1 |
| 1980 | 1,325 | 290 | 1,035 | 1,546 | 338 | 1,207 | 21.9 | 78.1 |
| 1981 | 1,614 | 301 | 1,313 | 1,718 | 320 | 1,397 | 18.6 | 81.4 |
| 1982 | 1,880 | 380 | 1,500 | 1,880 | 380 | 1,500 | 20.2 | 79.8 |
| 1983 | 2,152 | 460 | 1,692 | 2,072 | 443 | 1,629 | 21.4 | 78.6 |
| 1984 | 2,475 | 471 | 2,004 | 2,297 | 437 | 1,860 | 19.0 | 81.0 |
| 1985 | 2,628 | 476 | 2,152 | 2,364 | 428 | 1,936 | 18.1 | 81.9 |
| 1986 (Est.) | 2,794 | 524 | 2,270 | 2,450 | 459 | 1,990 | 18.8 | 81.2 |
| 1987 (Est.) | 3,000 | 600 | 2,400 | 2,545 | 509 | 2,036 | 20.0 | 80.0 |

Note: Data include federally funded R&D centers administered by industry. Detail may not add to totals because of rounding.

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: 1960-64: National Science Foundation, *National Patterns of Science and Technology Resources, 1981* (NSF 81-311), p 21. 1965-84: National Science Foundation, *National Patterns of Science and Technology Resources, 1984* (NSF 84-311), p 28. 1985-87 National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

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## Appendix table 4-17. Federal obligations for basic research in industry, by agency: 1967-88

| Year | All agencies | DOE[1] | DOD | NIH | NASA | NSF | All other agencies |
|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | |
| 1967 | $181 | $2 | $28 | $10 | $138 | $2 | $2 |
| 1968 | 195 | 2 | 21 | 8 | 163 | 1 | 1 |
| 1969 | 185 | 2 | 18 | 5 | 154 | 2 | 5 |
| 1970 | 185 | 1 | 30 | 6 | 146 | 1 | 1 |
| 1971 | 167 | 1 | 42 | 7 | 114 | 1 | 1 |
| 1972 | 151 | 1 | 37 | 10 | 97 | 2 | 4 |
| 1973 | 176 | 0 | 35 | 11 | 125 | 3 | 2 |
| 1974 | 124 | 1 | 38 | 16 | 64 | 3 | 3 |
| 1975 | 119 | 0 | 42 | 11 | 53 | 6 | 6 |
| 1976 | 131 | 0 | 41 | 14 | 66 | 6 | 3 |
| 1977 | 208 | 1 | 51 | 13 | 135 | 5 | 4 |
| 1978 | 248 | 2 | 57 | 14 | 153 | 12 | 9 |
| 1979 | 277 | 2 | 66 | 19 | 175 | 6 | 9 |
| 1980 | 325 | 4 | 88 | 18 | 195 | 11 | 10 |
| 1981 | 293 | 7 | 77 | 18 | 161 | 20 | 11 |
| 1982 | 271 | 6 | 100 | 13 | 119 | 20 | 12 |
| 1983 | 306 | 25 | 105 | 20 | 127 | 21 | 7 |
| 1984 | 394 | 22 | 91 | 28 | 215 | 24 | 14 |
| 1985 | 404 | 23 | 92 | 27 | 210 | 32 | 20 |
| 1986 | 545 | 19 | 94 | 34 | 314 | 58 | 27 |
| 1987 (Est.) | 647 | 36 | 91 | 41 | 383 | 61 | 35 |
| 1988 (Est.) | 571 | 27 | 99 | 35 | 300 | 73 | 36 |
| | As a percent of all agencies | | | | | | |
| 1967 | 100.0 | 1.0 | 15.6 | 5.3 | 76.3 | 0.8 | 0.9 |
| 1968 | 100.0 | 0.9 | 10.7 | 3.9 | 83.4 | 0.6 | 0.5 |
| 1969 | 100.0 | 0.9 | 9.5 | 2.8 | 83.4 | 0.8 | 2.5 |
| 1970 | 100.0 | 0.6 | 16.0 | 3.2 | 79.0 | 0.5 | 0.6 |
| 1971 | 100.0 | 0.6 | 25.4 | 4.0 | 68.6 | 0.7 | 0.6 |
| 1972 | 100.0 | 0.4 | 24.4 | 6.8 | 64.3 | 1.2 | 3.0 |
| 1973 | 100.0 | 0.1 | 20.1 | 6.2 | 71.2 | 1.4 | 1.1 |
| 1974 | 100.0 | 0.5 | 30.4 | 12.6 | 51.7 | 2.3 | 2.4 |
| 1975 | 100.0 | 0.1 | 35.3 | 9.6 | 45.0 | 5.5 | 4.7 |
| 1976 | 100.0 | 0.2 | 31.4 | 10.8 | 50.2 | 4.8 | 2.6 |
| 1977 | 100.0 | 0.3 | 24.5 | 6.1 | 64.7 | 2.4 | 2.0 |
| 1978 | 100.0 | 0.7 | 23.2 | 5.7 | 61.8 | 4.9 | 3.7 |
| 1979 | 100.0 | 0.7 | 23.8 | 7.0 | 63.0 | 2.3 | 3.3 |
| 1980 | 100.0 | 1.3 | 26.9 | 5.4 | 59.8 | 3.4 | 3.1 |
| 1981 | 100.0 | 2.5 | 26.1 | 6.2 | 54.9 | 6.7 | 3.6 |
| 1982 | 100.0 | 2.4 | 37.0 | 4.9 | 43.9 | 7.4 | 4.4 |
| 1983 | 100.0 | 8.3 | 34.2 | 6.6 | 41.7 | 6.9 | 2.4 |
| 1984 | 100.0 | 5.5 | 23.0 | 7.1 | 54.4 | 6.2 | 3.7 |
| 1985 | 100.0 | 5.7 | 22.9 | 6.6 | 51.9 | 8.0 | 4.9 |
| 1986 | 100.0 | 3.5 | 17.2 | 6.2 | 57.6 | 10.7 | 4.9 |
| 1987 (Est.) | 100.0 | 5.6 | 14.1 | 6.3 | 59.2 | 9.4 | 5.4 |
| 1988 (Est.) | 100.0 | 4.8 | 17.4 | 6.2 | 52.5 | 12.8 | 6.3 |

[1] Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 19[illegible] 1976, Department of Energy, 1977-present.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: FY 1955-1987;* National Science Foundation, *Federal Funds for Research and Development, FY 1986, 1987, and 1988,* vol. XXXVI

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## Appendix table 4-18. Federal obligations for basic research, by field: 1976-88

| Field | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 (Est.) | 1988 (Est.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | | | | | | | | |
| Total | 2,767,454 | 3,258,640 | 3,698,604 | 4,192,665 | 4,674,156 | 5,041,295 | 5,481,605 | 6,260,131 | 7,067,359 | 7,818,682 | 8,153,0[illegible]6 | 8,821,058 | 9,134,074 |
| Total sciences | 2,494,655 | 2,920,957 | 3,306,043 | 3,758,007 | 4,208,928 | 4,515,277 | 4,871,138 | 5,570,628 | 6,222,368 | 6,931,850 | 7,184,568 | 7,799,038 | 8,079,389 |
| Physical sciences | 721,435 | 889,994 | 941,421 | 1,050,002 | 1,220,588 | 1,324,[illegible] | 1,393,844 | 1,587,183 | 1,727,982 | 1,813,988 | 1,914,426 | 2,122,818 | 2,187,572 |
| Chemistry | 168,265 | 208,695 | 203,260 | 224,798 | 256,922 | 298,188 | 312,002 | 362,188 | 403,367 | 420,847 | 433,359 | 464,253 | 475,395 |
| Physics | 388,440 | 467,414 | 518,798 | 535,624 | 668,155 | 735,417 | 790,741 | 855,104 | 921,430 | 962,805 | 1,003,363 | 1,104,210 | 1,175,236 |
| Math & Computer sciences | 81,805 | 83,408 | 97,737 | 104,164 | 116,258 | 140,360 | 165,064 | 208,129 | 240,806 | 260,633 | 293,389 | 299,972 | 332,547 |
| Environmental sciences | 294,325 | 387,454 | 451,278 | 457,284 | 522,360 | 532,833 | 520,049 | 580,050 | 656,731 | 699,675 | 749,093 | 794,858 | 878,382 |
| Atmospheric sciences | 114,007 | 143,464 | 163,275 | 169,172 | 179,048 | 173,829 | 163,195 | 172,633 | 192,172 | 209,215 | 240,417 | 257,951 | 275,003 |
| Geological sciences | 95,705 | 128,720 | 145,114 | 157,603 | 198,335 | 194,205 | 177,487 | 178,292 | 198,010 | 249,988 | 265,478 | 267,905 | 300,168 |
| Oceanography | 76,580 | 104,593 | 120,720 | 119,110 | 130,678 | 143,294 | 154,465 | 195,615 | 220,131 | 219,258 | 224,304 | 249,040 | 283,755 |
| Life sciences | 1,222,015 | 1,383,365 | 1,588,390 | 1,891,777 | 2,054,425 | 2,223,848 | 2,526,017 | 2,891,336 | 3,287,634 | 3,807,527 | 3,858,783 | 4,168,840 | 4,270,998 |
| Psychology | 45,529 | 55,717 | 67,473 | 75,069 | 84,206 | 90,992 | 89,875 | 92,927 | 107,861 | 130,092 | 132,955 | 150,287 | 146,735 |
| Social sciences | 86,426 | 95,513 | 124,347 | 129,718 | 147,180 | 136,951 | 120,198 | 137,723 | 132,581 | 141,208 | 113,464 | 131,480 | 133,165 |
| Other sciences | 43,120 | 25,506 | 35,397 | 49,993 | 63,911 | 65,353 | 56,091 | 73,280 | 68,773 | 78,727 | 122,458 | 130,783 | 129,990 |
| Total engineering | 272,799 | 337,683 | 392,561 | 434,658 | 465,228 | 526,[illegible]8 | 610,467 | 689,503 | 844,991 | 886,832 | 968,508 | 1,022,020 | 1,054,685 |
| | Thousands of constant 1982 dollars[1] | | | | | | | | | | | | |
| Total | 4,457,883 | 4,861,465 | 5,157,005 | 5,382,112 | 5,515,879 | 5,408,534 | 5,481,605 | 6,006,074 | 6,532,359 | 7,000,342 | 7,098,891 | 7,467,246 | 7,423,059 |
| Total sciences | 4,018,452 | 4,357,686 | 4,609,653 | 4,824,142 | 4,966,873 | 4,844,198 | 4,871,138 | 5,344,553 | 5,751,334 | 6,205,330 | 6,255,610 | 6,602,081 | 6,565,940 |
| Physical sciences | 1,162,105 | 1,327,755 | 1,312,634 | 1,347,884 | 1,440,392 | 1,421,457 | 1,393,844 | 1,522,770 | 1,597,173 | 1,624,127 | 1,666,892 | 1,797,019 | 1,777,791 |
| Chemistry | 271,045 | 311,346 | 283,408 | 288,573 | 305,189 | 319,910 | 312,002 | 347,489 | 372,832 | 376,799 | 377,326 | 393,002 | 386,343 |
| Physics | 625,709 | 697,321 | 723,366 | 687,579 | 788,477 | 788,989 | 790,741 | 820,401 | 851,678 | 862,033 | 873,629 | 934,741 | 955,088 |
| Math & Computer sciences | 131,774 | 124,434 | 136,276 | 133,715 | 137,194 | 150,585 | 165,064 | 199,682 | 222,577 | 233,354 | 255,454 | 253,934 | 270,254 |
| Environmental sciences | 474,106 | 578,031 | 629,222 | 587,014 | 616,427 | 571,648 | 520,049 | 556,510 | 607,016 | 626,444 | 652,236 | 672,867 | 713,842 |
| Atmospheric sciences | 183,645 | 214,030 | 227,656 | 217,166 | 211,291 | 186,492 | 163,195 | 165,627 | 177,625 | 187,318 | 209,331 | 218,362 | 223,489 |
| Geological sciences | 154,164 | 192,033 | 202,334 | 202,315 | 234,051 | 208,352 | 177,487 | 171,056 | 183,021 | 223,823 | 231,152 | 226,788 | 243,940 |
| Oceanography | 123,357 | 156,039 | 168,321 | 152,901 | 154,211 | 153,732 | 154,465 | 187,676 | 203,467 | 196,309 | 195,302 | 210,819 | 230,601 |
| Life sciences | 1,968,452 | 2,063,800 | 2,214,710 | 2,428,469 | 2,424,386 | 2,385,847 | 2,526,017 | 2,773,996 | 3,038,760 | 3,409,013 | 3,359,846 | 3,529,027 | 3,470,945 |
| Psychology | 73,339 | 83,122 | 94,078 | 96,366 | 99,370 | 97,620 | 89,875 | 89,156 | 99,696 | 116,476 | 115,764 | 127,222 | 119,248 |
| Social sciences | 139,217 | 142,493 | 173,378 | 166,519 | 173,684 | 146,927 | 120,198 | 132,134 | 122,545 | 126,429 | 98,793 | 111,301 | 108,220 |
| Other sciences | 69,459 | 38,052 | 49,354 | 64,176 | 75,420 | 70,114 | 56,091 | 70,306 | 63,567 | 70,487 | 106,6[illegible] | 110,711 | 105,640 |
| Total engineering | 439,431 | 503,779 | 547,352 | 557,969 | 549,006 | 564,336 | 610,467 | 661,521 | 781,025 | 794,012 | 843,281 | 865,165 | 857,119 |

[1] GNP implicit price deflator used to convert current to constant dollars.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, FY 1955-87*; National Science Foundation, *Federal Funds for Research and Development, FY 1986, 1987, and 1988*, vol XXXVI

## Appendix table 4-19. Expenditures for research and development by universities and colleges, by field: 1976-86

| Fields | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | | | | | | |
| Total | $3,729,007 | $4,066,953 | $4,624,673 | $5,361,408 | $6,060,629 | $6,809,552 | $7,266,122 | $7,798,179 | $8,508,380 | $9,527,293 | $10 718,402 |
| Total sciences | 3,297,280 | 3,568,480 | 4,023 611 | 4,593,001 | 5,195,705 | 5 848,875 | 6 240 609 | 6,687,368 | 7,301,276 | [illegible] | 9,109,309 |
| Physical sciences | 379 379 | 423,457 | 496,399 | 601,904 | 677,293 | 764,673 | 822,584 | [illegible] | 991,917 | 1,133,913 | 1,261,376 |
| Astronomy | 26,294 | 32,361 | 36,782 | 48,459 | 58,740 | 67,337 | 73,237 | 74 177 | 80,457 | 91,049 | 96,335 |
| Chemistry | 140 142 | 159,353 | 183,131 | 206,421 | 243,982 | 283,899 | 308,091 | 334,663 | 367,843 | 411,615 | 460,084 |
| Physics | 183 050 | 201,655 | 235,099 | 292,033 | 322,230 | 356,859 | 365,897 | 414,165 | 469,403 | 550,045 | 622,296 |
| Other physical sciences | 29,893 | 30 088 | 41,387 | 54,991 | 52,341 | 56,578 | 75,359 | 74,094 | 74,215 | 81,204 | 82,661 |
| Environmental sciences | 288,531 | 319,398 | 379,391 | 457,915 | 509,038 | 548,920 | 557,817 | 618,962 | 649 601 | 705,357 | 774,177 |
| Atmospheric | NA | NA | NA | NA | 67,459 | 78,257 | 85,443 | 97,660 | 102,875 | 109,549 | 124,826 |
| Earth sciences | NA | NA | NA | NA | 188,226 | 189,692 | 195,507 | 216,159 | 225 525 | 250,534 | 261,849 |
| Oceanography | NA | NA | NA | NA | 171,668 | 187,463 | 197,701 | 223,994 | 238,157 | 260,306 | 275,524 |
| Other environmental sciences | NA | NA | NA | NA | 81,685 | 93,508 | 79,166 | 81,149 | 83,044 | 84,968 | 111,978 |
| Mathematical sciences | 42,491 | 52,312 | 58,756 | 78,477 | 78,667 | 88,793 | 98,568 | 108,038 | 124,398 | 129,799 | 152,204 |
| Computer sciences | 44,503 | 55,563 | 67,422 | 97,921 | 114,196 | 132,884 | 149,259 | 175 236 | 222,480 | 279,181 | 315,360 |
| Life sciences | 2,101,695 | 2,258,806 | 2,538,004 | 2,832,523 | 3,217,658 | 3,670,596 | 3,969,593 | 4,233,143 | 4,617,226 | 5,155,422 | 5,746,125 |
| Agricultural sciences | 412,867 | 460,647 | 521,745 | 602,485 | 679,880 | 772,434 | 844,040 | 895,520 | 930,245 | 1,028,549 | 1,122,363 |
| Biological sciences | 710,724 | 772,290 | 808 500 | 914,806 | 1,030,429 | 1,186,333 | 1,286,548 | 1,408,240 | 1,555,330 | 1,697,690 | 1,832,910 |
| Medical sciences | 897,376 | 950,907 | 1 128,652 | 1,237,556 | 1,414,345 | 1,599,203 | 1,717,072 | 1,801,576 | [illegible] | 2,259,525 | 2,578,240 |
| Other life sciences | 80,728 | 74,962 | 79,107 | 77,676 | 93,004 | 112,626 | 121,933 | 127,807 | 141,848 | 169,658 | 212,612 |
| Psychology | 77 888 | 85,133 | 89,664 | 100,531 | 111,290 | 128,328 | 132,322 | 138,505 | 146,884 | 162,047 | 180,453 |
| Social sciences | 252,261 | 268,087 | 277,497 | 295,138 | 341,445 | 370,351 | 358,286 | 354,348 | 372,337 | 389,790 | 459,303 |
| Economics | 65,447 | 72,124 | 79,129 | 83,089 | 90,158 | 99,496 | 95,590 | 96,476 | 109,215 | 115,789 | 132,377 |
| Political science | 28,355 | 32,314 | 36 571 | 45,431 | 55,395 | 56,315 | 61,371 | 55,545 | 56,317 | 60,738 | 68,074 |
| Sociology | 66 246 | 61,939 | 66,900 | 74,641 | 88,556 | 94,658 | 80,252 | 78,327 | 74,626 | 78,643 | 88,311 |
| Other social sciences | 102,213 | 101,710 | 94,897 | 91,977 | 107,336 | 119,882 | 121,073 | 124,000 | 132,178 | [illegible] | 170,542 |
| Other sciences | 100,532 | 105 724 | 116,478 | 133,592 | 146,118 | 144,330 | 152,180 | 162,037 | 176,433 | [illegible] | 220,311 |
| Total engineering | 431,727 | 498,473 | 601,062 | 768,407 | 864,924 | 960,677 | 1,025,513 | 1,110,811 | 1,207,104 | 1,386,717 | 1,609,093 |
| Aeronautical and astronautical | NA | NA | NA | NA | 46,285 | 45,481 | 60,226 | 65,009 | 66,344 | 75,716 | 86,519 |
| Chemical | NA | NA | NA | NA | 67,557 | 83,207 | 83,548 | 90,767 | 96,199 | 108,927 | 125,122 |
| Civil | NA | NA | NA | NA | 88,641 | 108,174 | 108,711 | 109,921 | 133,692 | 147,428 | 171,012 |
| Electrical | NA | NA | NA | NA | 184,050 | 193,080 | 223,862 | 259,283 | 291,795 | 336,932 | 398,203 |
| Mechanical | NA | NA | NA | NA | 146,163 | 149,128 | 142,171 | 149,881 | 176,682 | 205,625 | 224,206 |
| Other engineering | NA | NA | NA | NA | 332,228 | 381,607 | 406,995 | 435,950 | 442,391 | 512,088 | 604,031 |
| | Thousands of constant 1982 dollars | | | | | | | | | | |
| Total | 5,912,489 | 6,044,817 | [illegible] | 6,823,734 | 7,070,262 | 7,247,288 | 7,266,122 | 7,508,356 | 7,897,874 | 8 570,022 | [illegible] |
| Total sciences | 5,227,969 | 5,303,924 | [illegible] | 5,845,744 | 6,061,252 | 6,224,856 | 6,240,609 | 6,438,829 | 6,777,384 | 7,319,939 | 7,987,119 |
| Physical sciences | 601,521 | 629,395 | 687,343 | 766,074 | 790,122 | 813,828 | 822,584 | 863,758 | 920,744 | 1,019,931 | 1,105,985 |
| Astronomy | 41,690 | 48,099 | 50,930 | 61,676 | 68,525 | 71,666 | 73,237 | 71,420 | 74,684 | 81,901 | 84,467 |
| Chemistry | 222,201 | 236,850 | 253,574 | 262,722 | 284,627 | 302,149 | 308,091 | 322,225 | 341,449 | 370,257 | 403,406 |
| Physics | 290,233 | 299,725 | 325,532 | [illegible] | 375,910 | 379,799 | 365,897 | 398,772 | 435,722 | 494,778 | 545,634 |
| Other physical sciences | 47,397 | 44,721 | 57,307 | 69,990 | 61,060 | 60,215 | 75,359 | 71,340 | 68,890 | 73,045 | 72,478 |
| Environmental sciences | 457 477 | 474,729 | 525,327 | 576,448 | 593,838 | 584,206 | 557,817 | 595,958 | 602,990 | 634,485 | 678,805 |
| Atmospheric | NA | NA | NA | NA | 78,697 | 83,288 | 85,443 | 94,030 | 95,493 | 98,542 | 109,448 |
| Earth sciences | NA | NA | NA | NA | 219,582 | 201,886 | 195,507 | 208,125 | 209,343 | 225,361 | 229,591 |
| Oceanography | NA | NA | NA | NA | 200,266 | 199,514 | 197,701 | 215,669 | 221,068 | 234,151 | 241,582 |
| Other environmental sciences | NA | NA | NA | NA | 95,293 | 99,519 | 79,166 | 78,133 | 77,085 | 76,431 | 98,183 |
| Mathematical sciences | 67,371 | 77,753 | 81,357 | 99,882 | 91,772 | 94,501 | 98,568 | 104,023 | 115,472 | 116,757 | 133,454 |
| Computer sciences | 70,561 | 82,585 | 93,356 | 124,629 | 133,220 | 141,426 | 149,259 | 168,723 | 206,516 | 251,130 | 276,510 |
| Life sciences | 3,332,321 | 3,357,322 | 3,514,268 | 3,605,095 | 3,753,684 | 3,906,552 | 3,969,593 | 4,075,816 | 4,285,924 | 4,637,422 | 5,038,251 |
| Agricultural sciences | 654,617 | 684,672 | 722,438 | 766,813 | 793,140 | 822,088 | 844,040 | 862,238 | 863,497 | 925,204 | 984,097 |
| Biological sciences | 1 126,881 | 1,147,875 | 1,119,496 | 1,164,320 | 1,202,087 | 1,262,594 | 1,286,548 | 1,355,902 | 1,443,730 | 1,527,112 | 1,607,111 |
| Medical sciences | 1,422,825 | 1,413,358 | 1,562,797 | 1,575,100 | 1,649,959 | 1,702,004 | 1,717,072 | 1,734,620 | 1,847,028 | 2,032,495 | 2,260,623 |
| Other life sciences | 127,997 | 111,418 | 109,536 | 98,862 | 108,497 | 119,866 | 121,933 | 123,057 | 131,670 | 152,611 | 186,420 |
| Psychology | 123,495 | 126,535 | 124,154 | 127,951 | 129,830 | 136,577 | 132,322 | 133,357 | 136,345 | 145,765 | 158,223 |
| Social sciences | 415,825 | 393,465 | 384,238 | 375,637 | 398,326 | 394,158 | 358,286 | 341,179 | 345,621 | 350,625 | 402,721 |
| Economics | 103,769 | 107,200 | 109,567 | 105,752 | 105,177 | 105,892 | 95,590 | 92,890 | 101,378 | 104,155 | 116,069 |
| Political science | 44,958 | 48,029 | 50,638 | 57,822 | 64,623 | 59,935 | 61,371 | 53,481 | 52,276 | 54,635 | 59,688 |
| Sociology | 105,036 | 92,062 | 92,634 | 94,999 | 103,308 | 100,743 | 80,252 | 75,416 | 69,271 | 70,741 | 77,432 |
| Other social sciences | 162,063 | 151,174 | 131,400 | 117,064 | 125,217 | 127,588 | 121,073 | 119,391 | 122,694 | 121,094 | 149,533 |
| Other sciences | 159,397 | 157,140 | 161,282 | 170,029 | 170,460 | 153,608 | 152,180 | 156,015 | 163,773 | 163,773 | 193,171 |
| Total engineering | 684,520 | 740,893 | 832,265 | 977,990 | 1,009,011 | 1,022,432 | 1,025,513 | 1,069,527 | 1,120,490 | 1,247,384 | 1,410,866 |
| Aeronautical and astronautical | NA | NA | NA | NA | 53,996 | 48,405 | 60,226 | 62,593 | 61,584 | 68,108 | 75,861 |
| Chemical | NA | NA | NA | NA | 78,811 | 88,556 | 83,548 | 87,394 | 89,296 | 97,982 | 109,708 |
| Civil | NA | NA | NA | NA | 103,408 | 115,128 | 108,711 | 105,836 | 124,099 | 132,615 | 149,945 |
| Electrical | NA | NA | NA | NA | 214,711 | 205,492 | 223,862 | 249,647 | 270,858 | 303,078 | 349,148 |
| Mechanical | NA | NA | NA | NA | [illegible] | 158,714 | 142,171 | 144,311 | 164,004 | 184,964 | 196,586 |
| Other engineering | NA | NA | NA | NA | 387,573 | 406,138 | 406,995 | 419,748 | 410,648 | 460,635 | 529,619 |

Note. NA not available

SOURCE National Science Foundation *Academic Science and Engineering R&D Funds 1985* and unpublished data

See figure O-24 in Overview

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## Appendix table 4-20. Research and development expenditures at universities and colleges, by field and source of funds: 1986

| Field and source of funds | Total (Thousands of dollars) | Federal (Thousands of dollars) | Federal (Percent) | Non-federal (Thousands of dollars) | Non-federal (Percent) |
|---|---|---|---|---|---|
| | Thousands of dollars | | | | |
| Total | $10,718,402 | $6,633,347 | 61.9 | $4,085,055 | 38.1 |
| Source of funds: | | | | | |
| Federal government | 6,633,347 | 6,633,347 | 100.0 | 0 | 0.0 |
| State and local governments | 902,963 | 0 | 0.0 | 902,963 | 100.0 |
| Industry | 667,362 | 0 | 0.0 | 667,362 | 100.0 |
| Institutional funds | 1,774,421 | 0 | 0.0 | 1,774,421 | 100.0 |
| Other source of funds | 740,309 | 0 | 0.0 | 740,309 | 100.0 |
| Fields: | | | | | |
| Total sciences | 9,109,309 | 5,664,873 | 62.2 | 3,444,436 | 37.8 |
| Physical sciences | 1,261,376 | 975,516 | 77.3 | 285,859 | 22.7 |
| Astronomy | 96,335 | 64,009 | 66.4 | 32,326 | 33.6 |
| Chemistry | 460,084 | 337,913 | 73.4 | 122,171 | 26.6 |
| Physics | 622,296 | 509,574 | 81.9 | 112,722 | 18.1 |
| Other physical sciences | 82,661 | 64,021 | 77.5 | 18,640 | 22.5 |
| Environmental sciences | 774,177 | 520,137 | 67.2 | 254,039 | 32.8 |
| Atmospheric | 124,826 | 99,485 | 79.7 | 25,341 | 20.3 |
| Earth sciences | 261,849 | 150,942 | 57.6 | 110,906 | 42.4 |
| Oceanography | 275,524 | 207,095 | 75.2 | 68,429 | 24.8 |
| Other environmental sciences | 111,978 | 62,615 | 55.9 | 49,364 | 44.1 |
| Mathematical sciences | 152,204 | 112,364 | 73.8 | 39,840 | 26.2 |
| Computer sciences | 315,360 | 227,428 | 72.1 | 87,932 | 27.9 |
| Life sciences | 5,746,125 | 3,439,947 | 59.9 | 2,306,178 | 40.1 |
| Agricultural sciences | 1,122,363 | 298,075 | 26.6 | 824,288 | 73.4 |
| Biological sciences | 1,832,910 | 1,278,995 | 69.8 | 553,916 | 30.2 |
| Medical sciences | 2,578,240 | 1,738,382 | 67.4 | 839,858 | 32.6 |
| Other life sciences | 212,612 | 124,495 | 58.6 | 88,117 | 41.4 |
| Psychology | 180,453 | 118,449 | 65.6 | 62,004 | 34.4 |
| Social sciences | 459,303 | 166,948 | 36.3 | 292,355 | 63.7 |
| Economics | 132,377 | 42,878 | 32.4 | 89,499 | 67.6 |
| Political science | 68,074 | 19,731 | 29.0 | 48,343 | 71.0 |
| Sociology | 88,311 | 43,685 | 49.5 | 44,626 | 50.5 |
| Other social sciences | 170,542 | 60,655 | 35.6 | 109,887 | 64.4 |
| Other sciences | 220,311 | 104,083 | 47.2 | 116,228 | 52.8 |
| Total engineering | 1,609,093 | 968,474 | 60.2 | 640,619 | 39.8 |
| Aeronautical and astronautical | 86,519 | 67,345 | 77.8 | 19,174 | 22.2 |
| Chemical | 125,122 | 66,135 | 52.9 | 58,987 | 47.1 |
| Civil | 171,012 | 91,517 | 53.5 | 79,495 | 46.5 |
| Electrical | 398,203 | 265,885 | 66.8 | 132,317 | 33.2 |
| Mechanical | 224,206 | 144,529 | 64.5 | 79,677 | 35.5 |
| Other engineering | 604,031 | 333,063 | 55.1 | 270,968 | 44.9 |

SOURCE: National Science Foundation, *Academic Science and Engineering, R&D funds, 1986*, and unpublished data

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## Appendix table 4-21. Basic research expenditures in industry, by field: 1973-83

| Field | 1973 | 1975 | 1977 | 1979 | 1981 | 1983 |
|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | |
| Total | $631 | $730 | $911 | $1,158 | $1,614 | $2,104 |
| Total sciences | 446 | 538 | 677 | 865 | 1,156 | 1,422 |
| Physical sciences | 276 | 320 | 405 | 527 | 746 | 902 |
| Chemistry | 193 | 228 | 285 | 381 | 485 | 555 |
| Mathematics | 14 | 14 | 19 | 20 | 26 | 27 |
| Environmental sciences | 7 | 15 | 19 | 13 | 18 | 29 |
| Atmospheric sciences | 2 | 6 | 5 | 5 | 12 | 16 |
| Geological sciences | 3 | 5 | 7 | 6 | 6 | 13 |
| Oceanography | 1 | 3 | 7 | 2 | 0 | 0 |
| Life sciences | 102 | 122 | 156 | 177 | 208 | 276 |
| Biological sciences | 77 | 85 | 128 | 136 | 157 | 241 |
| Clinical medical sciences | 25 | 37 | 28 | 40 | 51 | 35 |
| Other sciences | 47 | 67 | 78 | 128 | 158 | 188 |
| Total engineering | 185 | 191 | 233 | 292 | 458 | 682 |
| | Millions of constant 1982 dollars[1] | | | | | |
| Total | 1,274 | 1,231 | 1,354 | 1,474 | 1,718 | 2,026 |
| Total sciences | 900 | 907 | 1,006 | 1,101 | 1,230 | 1,369 |
| Physical sciences | 557 | 540 | 602 | 671 | 794 | 868 |
| Chemistry | 390 | 384 | 424 | 485 | 516 | 534 |
| Mathematics | 28 | 24 | 28 | 25 | 28 | 26 |
| Environmental sciences | 14 | 25 | 28 | 17 | 19 | 28 |
| Atmospheric sciences | 4 | 10 | 7 | 6 | 13 | 15 |
| Geological sciences | 6 | 8 | 10 | 8 | 6 | 13 |
| Oceanography | 2 | 5 | 10 | 3 | 0 | 0 |
| Life sciences | 206 | 206 | 232 | 225 | 221 | 266 |
| Biological sciences | 155 | 143 | 190 | 173 | 167 | 232 |
| Clinical medical sciences | 50 | 62 | 42 | 51 | 54 | 34 |
| Other sciences | 95 | 113 | 116 | 163 | 168 | 181 |
| Total engineering | 373 | 322 | 346 | 372 | 487 | 657 |

[1] GNP implicit price deflator used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation. *Research and Development in Industry, 1984.* and unpublished data

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## Appendix table 4-22. Plant and equipment expenditures in academic science and engineering, by source of funds: 1964-86

| Years | Capital fund expenditures[1]: Total, Current dollars | Capital fund expenditures[1]: Total, Constant 1982 dollars | Capital fund expenditures[1]: Federal sources, Current dollars | Capital fund expenditures[1]: Federal sources, Constant 1982 dollars | Capital fund expenditures[1]: Non-federal sources, Current dollars | Capital fund expenditures[1]: Non-federal sources, Constant 1982 dollars | Current fund equipment expenditures[2]: Current dollars | Current fund equipment expenditures[2]: Constant 1982 dollars |
|---|---|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | | | |
| 1964 ...... | 529,492 | 1,607,932 | 134,439 | 408,257 | 395,053 | 1,199,675 | NA | NA |
| 1965 ...... | NA | NA | NA | NA | NA | NA | NA | NA |
| 1966 ...... | 666,997 | 1,907,886 | 212,397 | 607,543 | 454,600 | 1,300,[illegible]43 | NA | NA |
| 1967 ...... | NA | NA | NA | NA | NA | NA | NA | NA |
| 1968 ...... | 1,070,727 | 2,837,866 | 340,447 | 902,324 | 730,280 | 1,935,542 | NA | NA |
| 1969 ...... | NA | NA | NA | NA | NA | NA | NA | NA |
| 1970 ...... | 951,873 | 2,264,747 | 279,316 | 664,563 | 672,557 | 1,600,183 | NA | NA |
| 1971 ...... | NA | NA | NA | NA | NA | NA | NA | NA |
| 1972 ...... | 912,487 | 1,962,760 | 236,836 | 509,434 | 675,651 | 1,453,325 | NA | NA |
| 1973 ...... | 835,862 | 1,687,247 | 224,651 | 453,474 | 611,211 | 1,233,773 | NA | NA |
| 1974 ...... | 841,560 | 1,559,600 | 225,681 | 418,238 | 615,879 | 1,141,362 | NA | NA |
| 1975 ...... | 1,018,773 | 1,717,709 | 270,083 | 455,375 | 748,690 | 1,262,334 | NA | NA |
| 1976 ...... | 1,043,153 | 1,653,961 | 206,890 | 328,032 | 836,263 | 1,325,928 | NA | NA |
| 1977 ...... | 960,014 | 1,426,894 | 195,519 | 290,605 | 764,495 | 1,136,289 | NA | NA |
| 1978 ...... | NA | NA | NA | NA | NA | NA | NA | NA |
| 1979 ...... | 696,218 | 886,112 | 164,460 | 209,317 | 531,758 | 676,795 | NA | NA |
| 1980 ...... | 794,512 | 926,869 | 149,563 | 174,479 | 644,949 | 752,390 | 363,040 | 423,518 |
| 1981 ...... | 952,672 | 1,013,912 | 153,800 | 163,687 | 798,872 | 850,226 | 413,972 | 440,583 |
| 1982 ...... | 969,147 | 969,147 | 116,651 | 116,651 | 852,496 | 852,496 | 408,479 | 408,479 |
| 1983 ...... | 1,098,941 | 1,058,098 | 131,517 | 126,629 | 967,424 | 931,469 | 435,178 | 419,004 |
| 1984 ...... | 1,215,249 | 1,128,051 | 141,728 | 131,559 | 1,073,521 | 996,492 | 518,125 | 480,948 |
| 1985 ...... | 1,312,657 | 1,180,765 | 144,296 | 129,798 | 1,168,361 | 1,050,968 | 654,652 | 588,875 |
| 1986 ...... | 1,578,818 | 1,384,321 | 193,120 | 169,329 | 1,385,698 | 1,214,992 | 764,848 | 670,625 |

[1] Data includes expenditures from capital funds for facilities and equipment for research, development, and instruction.

[2] Data include funds spent from current operating funds for research equipment These expenditures are not included in the total expenditures column

Note: NA not available

SOURCES: National Science Foundation, *Academic Science/Engineering. R&D Funds. Fiscal Year 1986. Detailed Statistical Tables* (forthcoming), and previous annual publications of the same name for earlier fiscal years

See figure O-23 in Overview.

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## Appendix table 4-23. Capital expenditures[1] at universities and colleges by field and source of funds: 1972-77 and 1979-86

| Field | 1972 | 1973 | 1974 | 1975 | 1976 | 1977[2] | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | | | | | | | | | |
| Total | 912,487 | 835,862 | 841,560 | 1,018,773 | 1,043,153 | 960,014 | 696,218 | 794,51[illegible] | 952,672 | 969,147 | 1,098,941 | 1,215,249 | 1,312,657 | 1,578,818 |
| Engineering | 84,950 | 55,800 | 91,701 | 118,315 | 81,678 | 87,718 | 87,128 | 89,297 | 103,329 | 144,457 | 134,980 | 142,894 | 187,320 | 316,440 |
| Total sciences | 827,537 | 780,062 | 749,859 | 900,458 | 961,475 | 872,296 | 609,090 | 705,215 | 849,343 | 824,690 | 963,961 | 1,072,355 | 1,125,337 | 1,262,378 |
| Physical sciences | 137,331 | 106,210 | 93,468 | 80,642 | 73,755 | 65,216 | 64,685 | 77,154 | 87,813 | 82,100 | 97,467 | 116,071 | 131,108 | 152,808 |
| Environmental sciences | 27,187 | 26,739 | 24,588 | 35,278 | 49,304 | 28,351 | 25,153 | 36,208 | 35,025 | 42,365 | 41,112 | 36,814 | 54,053 | 47,111 |
| Mathematical/computer sciences | 24,712 | 20,016 | 23,670 | 15,227 | 24,684 | 25,136 | 27,282 | 32,318 | 30,517 | 34,328 | 53,098 | 49,971 | 75,657 | 91,088 |
| Life sciences | 517,941 | 488,705 | 495,078 | 669,093 | 706,961 | 642,493 | 428,293 | 459,057 | 597,635 | 590,353 | 678,778 | 741,416 | 751,646 | 839,906 |
| Psychology | 19,007 | 39,584 | 15,511 | 11,710 | 9,131 | 12,702 | 7,060 | 17,982 | 10,991 | 12,798 | 17,012 | 35,205 | 20,900 | 25,472 |
| Social sciences | 59,993 | 61,215 | 59,329 | 50,904 | 44,303 | 31,798 | 21,358 | 35,073 | 45,138 | 30,797 | 40,870 | 51,933 | 61,849 | 50,711 |
| Other sciences, N.E.C. | 41,366 | 37,593 | 38,218 | 37,604 | 53,337 | 66,600 | 35,259 | 47,423 | 42,224 | 31,949 | 35,624 | 40,946 | 30,125 | 55,282 |
| Federal sources | 236,836 | 224,651 | 225,681 | 270,083 | 206,890 | 195,519 | 164,460 | 149,563 | 153,800 | 116,651 | 131,517 | 141,728 | 144,296 | 193,120 |
| Engineering | 21,082 | 13,547 | 42,702 | 64,019 | 20,200 | 17,219 | 20,927 | 20,438 | 17,601 | 18,136 | 16,163 | 24,013 | 16,778 | 33,635 |
| Total sciences | 215,754 | 211,104 | 182,979 | 206,064 | 186,690 | 178,300 | 143,533 | 129,125 | 136,199 | 98,515 | 115,354 | 117,715 | 127,519 | 159,485 |
| Physical sciences | 27,892 | 24,496 | 20,721 | 18,862 | 19,195 | [illegible] 894 | 32,186 | 22,463 | 25,529 | 20,154 | 18,579 | 18,916 | 31,300 | 35,089 |
| Environmental sciences | 8,486 | 5,961 | 7,084 | 5,960 | 6,428 | 9,307 | 8,220 | 8,033 | 6,866 | 4,404 | 3,644 | 3,490 | 3,547 | 6,184 |
| Mathematical/computer sciences | 4,341 | 3,022 | 4,257 | 2,584 | 2,052 | 1,882 | 2,983 | 5,653 | 4,944 | 3,798 | 4,458 | 5,296 | 6,718 | 14,048 |
| Life sciences | 152,328 | 161,907 | 139,775 | 169,459 | 153,570 | 137,369 | 90,796 | 86,105 | 89,410 | 66,004 | 81,016 | 85,412 | 80,829 | 94,310 |
| Psychology | 3,663 | 5,119 | 2,536 | 2,245 | 1,967 | 2,398 | 1,740 | 2,002 | 1,580 | 1,023 | 1,365 | 1,008 | 820 | 1,266 |
| Social sciences | 10,939 | 5,369 | 4,467 | 2,755 | 1,806 | 2,109 | 2,076 | 1,528 | 6,376 | 1,374 | 4,959 | 2,932 | 2,096 | 2,505 |
| Other sciences, N.E.C. | 8,105 | 5,230 | 4,139 | 4,199 | 1,672 | 3,341 | 5,532 | 3,341 | 1,494 | 1,758 | 1,333 | 660 | 2,209 | 6,0[illegible] |
| Other sources | 675,651 | 611,211 | 615,879 | 748,690 | 836,263 | 764,495 | 531,758 | 644,949 | 798,872 | 852,496 | 967,424 | 1,073,521 | 1,168,361 | 1,385,698 |
| Engineering | 63,868 | 42,253 | 48,999 | 54,296 | 61,478 | 70,499 | 66,201 | 68,859 | 85,728 | 126,321 | 118,817 | 118,881 | 170,542 | 282,805 |
| Total sciences | 611,783 | 568,958 | 566,880 | 694,394 | 774,785 | 693,996 | 465,557 | 576,090 | 713,144 | 726,175 | 848,607 | 954,640 | 997,818 | 1,102,893 |
| Physical sciences | 109,439 | 81,714 | 72,747 | 61,780 | 54,560 | 43,322 | 32,499 | 54,691 | 62,284 | 61,946 | 78,888 | 97,154 | 99,808 | 117,719 |
| Environmental sciences | 18,701 | 20,778 | 17,504 | 29,318 | 42,876 | 19,044 | 16,933 | 28,175 | 28,159 | 37,961 | 37,468 | 33,324 | 50,506 | 40,927 |
| Mathematical/computer sciences | 20,371 | 16,994 | 19,413 | 12,643 | 22,632 | 23,254 | 24,299 | 26,665 | 25,573 | 30,530 | 48,640 | 44,675 | 68,939 | 77,040 |
| Life sciences | 365,613 | 326,798 | 355,303 | 499,634 | 553,391 | 505,124 | 337,497 | 372,952 | 508,225 | 524,349 | 597,762 | 656,004 | 670,817 | 745,596 |
| Psychology | 15,344 | 34,465 | 12,975 | 9,465 | 7,164 | 10,304 | 5,320 | 15,980 | 9,411 | 11,775 | 15,647 | 34,197 | 20,080 | 24,206 |
| Social sciences | 49,054 | 55,846 | 54,862 | 48,149 | 42,497 | 29,689 | 19,282 | 33,545 | 38,762 | 29,423 | 35,911 | 49,001 | 59,753 | 48,206 |
| Other sciences, N.E.C. | 33,261 | 32,363 | 34,076 | 33,405 | 51,665 | 63,259 | 29,727 | 44,082 | 40,730 | 30,191 | 34,291 | 40,286 | 27,916 | 49,200 |

Note: NA = Not available.

[1] Includes expenditures for facilities and equipment for research, development and instruction.

[2] Data were not collected in 1978.

SOURCE: National Science Foundation, *Academic Science and Engineering: R&D Funds 1986*

## Appendix table 4-24. Academic officials' views regarding condition of research facilities: 1986

| Field | Number of interviews | Condition of research facilities | | | | |
|---|---|---|---|---|---|---|
| | | Excellent | Good | Fair | Poor | Don't know[1] |
| | | Percent | | | | |
| Research administrators | 80 | 4 | 44 | 45 | 4 | 4 |
| Deans: | | | | | | |
| Engineering | 29 | 7 | 34 | 48 | 10 | 0 |
| Physical sciences | 39 | 0 | 31 | 51 | 10 | 8 |
| Life sciences | 39 | 8 | 38 | 41 | 10 | 3 |
| Environmental sciences | 33 | 3 | 21 | 52 | 21 | 3 |
| Medical sciences | 25 | 8 | 48 | 28 | 8 | 8 |
| Computer sciences | 37 | 14 | 32 | 41 | 14 | 0 |
| Mathematical sciences | 39 | 0 | 38 | 44 | 10 | 8 |
| Psychology | 38 | 3 | 37 | 26 | 24 | 11 |
| Social sciences | 39 | 5 | 33 | 44 | 15 | 3 |

[1] Some deans were unable to select one response, due primarily to variation in the condition of facilities in the discipline.

SOURCE: National Science Foundation, *Science and Engineering Facilities at Doctorate-Granting Institutions*, September 1986

See figure 4-3.

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## Appendix table 4-25. Academic officials' views on sufficiency of research space: 1986

| Field | Number of interviews | Amount of research space | | |
|---|---|---|---|---|
| | | More than needed | About right | Less than needed |
| | | Percent | | |
| Research administrators | 80 | 0 | 5 | 95 |
| Deans: | | | | |
| Engineering | 29 | 0 | 7 | 93 |
| Physical sciences | 39 | 0 | 21 | 79 |
| Life sciences | 39 | 0 | 18 | 82 |
| Environmental sciences | 33 | 0 | 27 | 73 |
| Medical sciences | 25 | 0 | 28 | 72 |
| Computer sciences | 37 | 3 | 11 | 86 |
| Mathematical sciences | 39 | 3 | 33 | 64 |
| Psychology | 38 | 3 | 16 | [illegible] |
| Social sciences | 39 | 0 | 8 | 92 |

SOURCE: National Science Foundation, *Science and Engineering Research Facilities at Doctorate-Granting Institutions*, September 1986

See figure 4-4.

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## Appendix table 4-26. Current fund expenditures for research equipment at universities and colleges, by field: 1980-86

| Years | Total | Engineering | Physical science | Environmental science | Mathematical science | Computer science | Life science | Psychology | Social science | Other science |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands of dollars | | | | | | | | | |
| Total: | | | | | | | | | | |
| 1980 | $363,040 | $56,584 | $53,859 | $28,613 | $2,060 | $8,248 | $188,718 | $5,447 | $12,805 | $6,706 |
| 1981 | 413,972 | 69,017 | 76,131 | 31,472 | 1,907 | 10,896 | 202,220 | 6,019 | 9,155 | 7,155 |
| 1982[1] | 403,479 | 65,861 | 78,126 | 28,321 | 2,556 | 12,672 | 199,574 | 5,784 | 7,143 | 8,461 |
| 1983 | 435,178 | 75,018 | 79,375 | 31,521 | 2,668 | 15,615 | 205,680 | 6,629 | 8,961 | 9,711 |
| 1984 | 518,125 | 90,650 | 107,450 | 40,806 | 4,539 | 19,056 | 225,575 | 7,066 | 12,727 | 10,257 |
| 1985 | 654,652 | 119,246 | 141,884 | 46,990 | 5,755 | 38,667 | 269,862 | 8,465 | 8,929 | 14,853 |
| 1986 | 764,848 | 138,894 | 164,084 | 50,7[illegible]4 | 4,961 | 46,549 | 318,062 | 9,018 | 12,152 | 20,414 |
| Federal: | | | | | | | | | | |
| 1980 | 240,816 | 35,804 | 44,453 | 19,512 | 1,439 | 3,434 | 122,385 | 4,126 | 6,391 | 3,272 |
| 1981 | 265,048 | 42,396 | 58,475 | 19,165 | 1,127 | 5,436 | 126,175 | 4,466 | 3,999 | 3,809 |
| 1982[1] | 266,780 | 43,220 | 62,642 | 18,423 | 1,617 | 8,215 | 120,189 | 4,219 | 2,907 | 5,306 |
| 1983 | 272,819 | 48,958 | 62,055 | 19,649 | 1,476 | 10,229 | 117,039 | 4,749 | 2,917 | 5,747 |
| 1984 | 335,495 | 59,278 | 86,746 | 29,477 | 3,213 | 14,056 | 128,837 | 3,016 | 3,484 | 5,387 |
| 1985 | 426,874 | 75,633 | 113,387 | 32,106 | 4,694 | 32,709 | 151,349 | 6,160 | 3,903 | 6,932 |
| 1986 | 496,664 | 80,992 | 133,410 | 35,431 | 3,405 | 39,226 | 182,722 | 6,055 | 3,779 | 11,644 |
| Non-federal: | | | | | | | | | | |
| 1980 | 122,224 | 20,780 | 9,406 | 9,101 | 621 | 4,814 | 66,333 | 1,32[illegible] | 6,414 | 3,434 |
| 1981 | 148,924 | 26,612 | 17,656 | 12,307 | 780 | 5,460 | 76,045 | 1,553 | 5,156 | 3,346 |
| 1982[1,2] | 141,699 | 22,641 | 15,484 | 9,898 | 939 | 4,457 | 79,385 | 1,565 | 4,236 | 3,155 |
| 1983 | 162,359 | 26,060 | 17,320 | 11,872 | 1,192 | 5,386 | 88,641 | 1,880 | 6,044 | 3,964 |
| 1984 | 182,632 | 31,372 | 20,705 | 11,329 | 1,326 | 4,999 | 96,737 | 2,050 | 9,243 | 4,870 |
| 1985 | 227,778 | 43,613 | 28,496 | 14,884 | 1,061 | 5,958 | 118,513 | 2,305 | 5,026 | 7,921 |
| 1986 | 268,184 | 57,902 | 30,674 | 15,283 | 1,557 | 7,323 | 135,340 | 2,963 | 8,373 | 8,771 |

[1] 1982 total has been revised but breakdown has not.

[2] Estimated

SOURCE: National Science Foundation, *Academic Science/Engineering: R&D Funds, 1986*

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## Appendix table 4-27. Expenditures under special Federal research instrumentation programs: 1981-85

| Fiscal year | Number of awards | Amount awarded | Mean size |
|---|---|---|---|
| Total | 3,464 | $320,482 | $93 |
| 1981 | 274 | 16,853 | 62 |
| 1982 | 319 | 22,901 | 72 |
| 1983 | 702 | 72,123 | 103 |
| 1984 | 951 | 96,227 | 101 |
| 1985 | 1,218 | 112,378 | 92 |

SOURCE: Abt Associates Inc., "Federal government programs that support science and engineering research instrumentation in academic institutions," AAI Report No. 86-1, April 24, 1986

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## Appendix table 4-28. Awards to colleges and universities under special Federal instrumentation programs, by R&D ranking of institutions

| Rank group[2] | Total FY 83 Federal R&D obligations | | Total instrumentation awards (4 agencies)[1] | | |
|---|---|---|---|---|---|
| | Thousands of dollars | Percent of total | Thousands of dollars | Percent of total | Number of awards |
| Total (1-641) .. | 4,860,431 | 100.0 | 325,397 | 100.0 | 4,387 |
| 1-100 ...... | 4,260,011 | 87.6 | 230,302 | 70.8 | 2,222 |
| 1-25 ..... | 2,341,202 | 48.2 | 114,219 | 35.1 | 1,086 |
| 26-50 .... | 986,191 | 20.3 | 60,045 | 18.5 | 524 |
| 51-100 ... | 932,618 | 19.2 | 56,038 | 17.2 | 612 |
| 101-641 .... | 600,420 | 12.4 | 95,095 | 29.2 | 1,265 |

[1] Combines totals 1981 to 1985 of special instrumentation programs of National Science Foundation, National Institutes of Health, Department of Energy, and Department of Defense.

[2] Rank by total federal fiscal year 1983 research and development obligations.

SOURCE: Abt Associates Inc. "Federal government programs that support science and engineering research instrumentation in academic institutions." AAI Report No. 86-1 April 24, 1986

See figure 4-5.

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## Appendix table 4-29. Instrument needs, 1982/83, versus awards under special Federal instrumentation programs, 1981-85

| Equipment type | Awards under special federal instrumentation programs: 1981-85 | | | Instruments named by department chairmen as most needed: 1982/83 | |
|---|---|---|---|---|---|
| | Number | Amount awarded | % of total | Number | Percent |
| Total .............................. | 3,368 | 308,866 | 100.0 | 560 | 100.0 |
| Computer ........................ | 560 | 48,807 | 16.6 | 157 | 28.0 |
| Laser ........................... | 160 | 16,439 | 4.8 | 32 | 5.7 |
| Sorters/sensors ................. | 69 | 4,790 | 2.0 | 8 | 1.4 |
| Microscopes/other ............... | 45 | 3,973 | 1.3 | 10 | 1.8 |
| Microscopes/electron ............. | 194 | 26,067 | 5.8 | 13 | 2.3 |
| Temperature equipment ........... | 64 | 3,392 | 1.9 | 11 | 2.0 |
| Spectrometers ................... | 701 | 78,377 | 20.8 | 95 | 17.0 |
| Acquisition/detectors, receivers ..... | 312 | 25,561 | 9.3 | 41 | 7.3 |
| Transmitters ..................... | 16 | 1,588 | 0.5 | 9 | 1.6 |
| Synthesis/preparation ............. | 89 | 6,340 | 2.6 | 5 | 0.9 |
| Image processors ................ | 205 | 18,458 | 6.1 | 28 | 5.0 |
| Separation technology ............ | 215 | 19,535 | 6.4 | 31 | 5.5 |
| Vacuum ......................... | 11 | 896 | 0.3 | 5 | 0.9 |
| Hydraulic ....................... | 10 | 1,032 | 0.3 | 6 | 1.1 |
| Magnetic ........................ | 18 | 1,202 | 0.5 | 7 | 1.3 |
| Not identified ..................... | 699 | 52,410 | 20.8 | 102 | 18.2 |

Note: Department chairmen were asked to name the three items of equipment in the $10,000 to $100,000 range which were most needed in their departments or facilities.

SOURCE: Abt Associates Inc, "Federal Government Programs that Support Science and Engineering Research Instrumentation in Academic Institutions," AAI Report No. 86-1, April 24, 1986

See figure 4-6.

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## Appendix table 4-30. Condition of academic research instrument systems, by system age

| | Number and percent of systems, by general working condition | | | |
|---|---|---|---|---|
| | Total | Excellent | Average | Poor |
| Total | [illegible]50 | 18,849 | 13,774 | 3,627 |
| | 100% | 52% | 38% | 10% |
| Age (from year of purchase):[1] | | | | |
| 1-5 years | 19,351 | 13,227 | 5,396 | 728 |
| | 100% | 68% | 28% | 4% |
| 6-10 years | 8,747 | 3,449 | 4,226 | 1,072 |
| | 100% | 39% | 48% | 12% |
| Over 10 years | 8,152 | 2,172 | 4,153 | 1,827 |
| | 100% | 27% | 51% | 22% |

Note: All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. For agricultural, biological and environmental sciences, estimates are as of December 1983. For all other fields, estimates are as of December 1982. Sample is 7013 instrument systems.

Note: Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary from table to table.

[1] For phase 2 fields, age intervals are 1-5 (1979-83); 6-10 years (1974-78); over 10 years (1973 or before). For phase 1 fields, intervals are 1-5 years (1978-82); 6-10 years (1973-77); over 10 years (1972 or before)

SOURCE: National Science Foundation, *Academic Research Equipment in Selected S/E Fields, 1982-83* (August 1985)

See figure 4-7.



## Appendix table 4-31. National stock of academic instrumentation, by field[1]

| Field | Instrument systems | Percent | Aggregate purchase price | Percent | Mean purchase price per system |
|---|---|---|---|---|---|
| Total | 46,738 | 100.0 | 1,630,780 | 100.0 | 35 |
| Engineering | 9,425 | 20.0 | 333,613 | 20.0 | 35 |
| Agricultural sciences | 1,954 | 4.0 | 42,599 | 3.0 | 22 |
| Biological sciences | 17 318 | 38.0 | 471,288 | 29.0 | 27 |
| Graduate shcools | 7,290 | 16.0 | 186,272 | 11.0 | 26 |
| Medical schools | 10,328 | 22.0 | 285,[illegible]6 | 17.0 | 28 |
| Computer sciences | 1,115 | 2.0 | 60,026 | 4.0 | 54 |
| Environmental sciences | 2,679 | 6.0 | 126,231 | 8.0 | 47 |
| Materials science | 73[illegible] | 2.0 | 37,120 | 2.0 | 51 |
| Physical sciences | 11,644 | 25.0 | 481,881 | 30.0 | 41 |
| Interdisciplinary, n.e.c | 1,571 | 3.0 | 78,022 | 5.0 | 50 |

Note. Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary slightly from field to field

[1] All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation For agricultural biological and environmental sciences). estimates are as of December 1983 For all other fields, estimates are as of December 1982 Sample is 8704 instrument systems

SOURCE. National Science Foundation, *Academic Research Equipment in Selected Science/Engineering Fields, 1982 83* (August 1985)

## Appendix table 4-32. Instrumentation-related expenditures in academic departments and facilities, by field

| Field | Total | Percent | Purchase of research equipment $500 or more | Percent | Purchase of research-related computer services | Percent | Maintenance/ repair of research equipment | Percent |
|---|---|---|---|---|---|---|---|---|
| Total | $640.6 | 100.0 | $414.5 | 65.0 | $121.3 | 19.0 | $104.8 | 16.0 |
| Engineering | 146.6 | 100.0 | 86.5 | 59.0 | 41.3 | 28.0 | 18.8 | 13.0 |
| Agricultural sciences | 40.6 | 100.0 | 28.4 | 70.0 | 7.3 | 18.0 | 5.0 | 12.0 |
| Biological sciences | 192.3 | 100.0 | 132.4 | 69.0 | 27.8 | 14.0 | 32.2 | 17.0 |
| Graduate schools | 79.0 | 100.0 | 51.8 | 66.0 | 13.2 | 17.0 | 14.0 | 18.0 |
| Medical schools | 113.3 | 100.0 | 80.5 | 71.0 | 14.5 | 13.0 | 18.3 | 16.0 |
| Computer science | 29.7 | 100.0 | 19.7 | 66.0 | 3.6 | 12.0 | 6.4 | 21.0 |
| Environmental sciences | 49.6 | 100.0 | 33.4 | 67.0 | 6.9 | 14.0 | 9.3 | 19.0 |
| Materials science | 12.4 | 100.0 | 9.6 | 77.0 | 0.6 | 4.0 | 2.3 | 18.0 |
| Physical science | 151.3 | 100.0 | 91.2 | 60.0 | 31.9 | 21.0 | 28.2 | 19.0 |
| Interdisciplinary, n.e.c | 17.8 | 100.0 | 13.3 | 75.0 | 1.9 | 11.0 | 2.6 | 14.0 |

Note: All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. For agricultural, biological and environmental sciences, estimates refer to expenditures in FY 1983. For all other fields, estimates are of expenditures in FY 1982. Sample is 912 departments and facilities.

Note: Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary slightly from table to table.

SOURCE: National Science Foundation. *Academic Research Equipment in Selected Science/Engineering Fields, 1982-83* (August 1985)

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## Appendix table 4-33. Equipment-intensiveness of academic research, by field: 1982/3

| Field | Total purchase price of national stock of academic research equipment (Millions of dollars) | Number of academic scientists and engineers January 1983 | Total price of national stock per scientist and engineer |
|---|---|---|---|
| Total | 1,516 | 107,000 | 14,200 |
| Engineering | 334 | 26,200 | 12,700 |
| Chemical | 27 | 2,100 | 12,900 |
| Civil | 22 | 4,400 | 5,000 |
| Electrical | 83 | 6,000 | 13,800 |
| Mechanical | 67 | 4,200 | 16,000 |
| Other, n.e.c | 134 | 9,400 | 14,300 |
| Agricultural sciences | 43 | 14,100 | 3,000 |
| Biological sciences | 471 | 34,000 | 13,900 |
| Computer sciences | 60 | 6,300 | 9,500 |
| Environmental sciences | 120 | 7,000 | 18,000 |
| Physical sciences | 402 | 19,400 | 24,800 |
| Chemistry | 255 | 9,400 | 27,100 |
| Physics and astronomy | 227 | 10,000 | 22,700 |

SOURCE: National Science Foundation. *Academic Research Equipment in Selected Science/Engineering Fields, 1982-83* (August 1985)

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## Appendix table 4-34. Instruments in shared-access facilities, by status and field: 1982/3

| Field | Percent of systems in shared-access facilities | | |
|---|---|---|---|
| | | Research status | |
| | Total | State-of-the-art systems | Other systems in research use |
| Total | 41 | 38 | 42 |
| Engineering | 50 | 50 | 49 |
| Agricultural sciences | 36 | 31 | 38 |
| Biological sciences | 35 | 32 | 36 |
| Graduate schools | 34 | 29 | 36 |
| Medical schools | 36 | 35 | 36 |
| Computer sciences | 81 | 73 | 83 |
| Environmental sciences | 48 | 46 | 49 |
| Materials sciences | 81 | 73 | 83 |
| Physical sciences | 35 | 27 | 37 |
| Interdisciplinary, n.e.c. | 73 | 84 | 68 |

SOURCE: National Science Foundation, *Academic Research Equipment In Selected Science/Engineering Fields, 1982-83* (August. 1985)

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## Appendix table 4-35. Instruments in shared-access facilities, by status, age, and field

| Field | Percent of systems in shared-access facilities | | | |
|---|---|---|---|---|
| | | System age (from year of purchase) | | |
| | Total | 1-5 years | 6-10 years | Over 10 years |
| Total | 41 | 38 | 41 | 48 |
| Engineering | 50 | 41 | 51 | 73 |
| Agricultural sciences | 36 | 38 | 36 | 32 |
| Biological sciences | 35 | 31 | 35 | 42 |
| Graduate schools | 34 | 30 | 37 | 41 |
| Medical schools | 36 | 33 | 34 | 44 |
| Computer sciences | 81 | 80 | 87 | 100 |
| Environmental sciences | 48 | 51 | 48 | 40 |
| Materials sciences | 81 | 75 | 68 | 90 |
| Physical sciences | 35 | 31 | 40 | 37 |
| Interdisciplinary, n.e.c | 73 | 67 | 78 | 73 |

SOURCE: National Science Foundation, *Academic Research Equipment In Selected Science/Engineering Fields, 1982-83* (August 1985)

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**Appendix table 4-36. Institutional co-authorship, by field and selected years: 1973, 1977, 1981, and 1984**

| Field | 1973 | 1977 | 1981 | 1984 |
|---|---|---|---|---|
| | Institutionally co-authored articles as a percent of all articles | | | |
| Total fields | 24.3 | 28.6 | 33.1 | 36.5 |
| Clinical medicine | 37.6 | 42.1 | 47.5 | 50.6 |
| Biomedicine | 25.7 | 30.1 | 34.4 | 38.5 |
| Biology | 19.4 | 22.7 | 26.7 | 30.2 |
| Chemistry | 14.9 | 18.3 | 21.3 | 23.8 |
| Physics | 19.3 | 23.5 | 26.7 | 29.9 |
| Earth and space sciences | 23.3 | 27.9 | 33.3 | 38.7 |
| Engineering and technology | 15.4 | 17.7 | 22.7 | 25.2 |
| Mathematics | 16.0 | 18.0 | 21.0 | 23.8 |
| | Institutionally co-authored articles | | | |
| Total fields | 66,106 | 75,283 | 95,858 | 104,456 |
| Clinical medicine | 28,617 | 32,643 | 41,239 | 44,293 |
| Biomedicine | 10,648 | 12,436 | 15,839 | 17,371 |
| Biology | 4,660 | 5,405 | 6,875 | 7,689 |
| Chemistry | 6,694 | 7,485 | 9,986 | 10,800 |
| Physics | 6,897 | 8,433 | 10,651 | 12,092 |
| Earth and space sciences | 2,798 | 3,085 | 4,146 | 4,914 |
| Engineering and technology | 4,412 | 4 437 | 5,562 | 5,791 |
| Mathematics | 1,379 | 1,359 | 1,561 | 1,506 |
| | Articles with at least one institutional address | | | |
| Total fields | 271,574 | 262,993 | 289,706 | 286,135 |
| Clinical medicine | 76,081 | 77,487 | 86,866 | 87,604 |
| Biomedicine | 41,370 | 41,314 | 46,052 | 45,161 |
| Biology | 24,064 | 23,761 | 25,707 | 25,492 |
| Chemistry | 45,002 | 40,905 | 46,807 | 45,440 |
| Physics | 35,791 | 35,897 | 39,919 | 40,418 |
| Earth and space sciences | 12,008 | 11,053 | 12,446 | 12,688 |
| Engineering and technology | 28,616 | 25,007 | 24,473 | 23,002 |
| Mathematics | 8,642 | 7,569 | 7,436 | 6,331 |

Note: Institutional co-authorship means that the address of more than one institution appears on the article

SOURCE Computer Horizons. Inc., *Science Indicators Literature Data Base*. Series 12, tabulations prepared for the National Science Foundation (January 1986)

See figure 5-11.



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## Appendix table 4-37. Relative changes in Federal obligations for defense and nondefense R&D, by character of work: 1960-88

| Year | Total | | | Basic research | | | Applied research | | | Development | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Defense | Nondefense | Total | Defense | Nondefense | Total | Defense | Nondefense | Total | Defense | Nondefense |
| | Billions constant 1982 dollars[1] | | | | | | | | | | | |
| 1967 .......... | 46.0 | 22.4 | 23.6 | 5.1 | 0.8 | 4.3 | 7.8 | 3.6 | 4.1 | 33.1 | 18.0 | 15.1 |
| 1968 .......... | 42.8 | 20.7 | 22.1 | 4.9 | 0.7 | 4.2 | 7.9 | 3.5 | 4.4 | 30.0 | 16.5 | 13.5 |
| 1969 .......... | 39.9 | 19.6 | 20.3 | 5.0 | 0.7 | 4.3 | 6.9 | 2.9 | 4.0 | 28.1 | 16.0 | 12.0 |
| 1970 .......... | 37.0 | 17.7 | 19.2 | 4.6 | 0.8 | 3.9 | 7.2 | 2.4 | 4.7 | 25.2 | 14.5 | 10.6 |
| 1971 .......... | 35.6 | 17.2 | 18.4 | 4.5 | 0.7 | 3.3 | 7.2 | 2.3 | 4.9 | 23.9 | 14.2 | 9.7 |
| 1972 .......... | 35.8 | 18.1 | 17.8 | 4.7 | 0.7 | 4.0 | 7.3 | 2.6 | 4.7 | 23.8 | 14.8 | 9.0 |
| 1973 .......... | 34.7 | 17.4 | 17.4 | 4.6 | 0.6 | 4.0 | 6.9 | 2.3 | 4.6 | 23.2 | 14.4 | 8.8 |
| 1974 .......... | 33.4 | 16.1 | 17.2 | 4.6 | 0.6 | 4.0 | 7.3 | 2.2 | 5.1 | 21.5 | 13.4 | 8.1 |
| 1975 .......... | 33.1 | 15.7 | 17.4 | 4.5 | 0.5 | 4.0 | 7.2 | 2.0 | 5.2 | 21.4 | 13.2 | 8.2 |
| 1976 .......... | 33.5 | 15.6 | 17.9 | 4.5 | 0.5 | 3.9 | 7.8 | 1.9 | 5.9 | 21.2 | 13.1 | 8.1 |
| 1977 .......... | 35.0 | 16.4 | 18.6 | 4.9 | 0.6 | 4.3 | 7.8 | 2.0 | 5.8 | 22.3 | 13.8 | 8.5 |
| 1978 .......... | 36.0 | 16.1 | 19.9 | 5.2 | 0.6 | 4.6 | 8.2 | 2.0 | 6.3 | 22.6 | 13.6 | 9.1 |
| 1979 .......... | 36.1 | 16.1 | 20.1 | 5.4 | 0.6 | 4.8 | 8.1 | 2.0 | 6.2 | 22.6 | 13.5 | 9.1 |
| 1980 .......... | 35.2 | 16.5 | 18.7 | 5.5 | 0.6 | 4.9 | 8.2 | 2.0 | 6.1 | 21.5 | 13.8 | 7.7 |
| 1981 .......... | 35.5 | 17.7 | 17.8 | 5.4 | 0.6 | 4.8 | 7.7 | 2.1 | 5.6 | 22.4 | 14.9 | 7.5 |
| 1982 .......... | 36.4 | 20.6 | 15.8 | 5.5 | 0.7 | 4.8 | 7.5 | 2.3 | 5.3 | 23.4 | 17.7 | 5.7 |
| 1983 .......... | 37.1 | 22.1 | 15.1 | 6.0 | 0.8 | 5.3 | 7.7 | 2.3 | 5.3 | 23.5 | 19.0 | 4.5 |
| 1984 .......... | 39.0 | 23.5 | 15.6 | 6.5 | 0.8 | 5.7 | 7.3 | 2.0 | 5.3 | 25.2 | 20.6 | 4.5 |
| 1985 .......... | 43.3 | 26.7 | 16.6 | 7.0 | 0.8 | 6.2 | 7.4 | 2.1 | 5.4 | 28.8 | 23.8 | 5.0 |
| 1986 (Est.) ..... | 44.8 | 28.7 | 16.1 | 7.1 | 0.8 | 6.3 | 7.3 | 2.0 | 5.3 | 30.4 | 25.9 | 4.5 |
| 1987 (Est.) ..... | 47.8 | 30.7 | 17.1 | 7.5 | 0.7 | 6.7 | 7.6 | 2.0 | 5.6 | 32.7 | 28.0 | 4.8 |
| 1988 (Est.) ..... | 51.5 | 34.7 | 16.9 | 7.4 | 0.7 | 6.7 | 7.2 | 2.0 | 5.2 | 36.9 | 31.9 | 5.0 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation. *Federal Funds for Research and Development. Detailed Historical Tables FY 1955 1986* National Science Foundation *Federal Funds for Research and Development. Fiscal Years 1985, 1987, and 1988*

See figure O-6 in Overview.

Science & Engineering Indicators—1987

## Appendix table 5-1. Academic research and development and basic research by performer: 1960-87

| Year | Total | Nonacademic basic research: Federal government | Industry | FFRDC's | Nonprofit Institutions | Academic research and development |
|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | |
| 1960 | $1,410 | $160 | $376 | $97 | $131 | $646 |
| 1961 | 1,628 | 206 | 395 | 115 | 149 | 763 |
| 1962 | 1,969 | 251 | 488 | 136 | 190 | 904 |
| 1963 | 2,232 | 255 | 522 | 159 | 215 | 1,081 |
| 1964 | 2,561 | 314 | 549 | 191 | 232 | 1,275 |
| 1965 | 2,891 | 364 | 592 | 208 | 253 | 1,474 |
| 1966 | 3,226 | 385 | 624 | 227 | 275 | 1,715 |
| 1967 | 3,520 | 435 | 629 | 250 | 285 | 1,921 |
| 1968 | 3,796 | 432 | 642 | 276 | 297 | 2,149 |
| 1969 | 3,955 | 532 | 618 | 275 | 305 | 2,225 |
| 1970 | 4,088 | 577 | 602 | 269 | 305 | 2,335 |
| 1971 | 4,258 | 586 | 590 | 260 | 322 | 2,500 |
| 1972 | 4,437 | 625 | 593 | 244 | 345 | 2,630 |
| 1973 | 4,777 | 608 | 631 | 297 | 357 | 2,884 |
| 1974 | 5,108 | 696 | 699 | 285 | 405 | 3,023 |
| 1975 | 5,607 | 734 | 730 | 309 | 425 | 3,409 |
| 1976 | 6,157 | 786 | 819 | 359 | 464 | 3,729 |
| 1977 | 6,804 | 914 | 911 | 402 | 510 | 4,067 |
| 1978 | 7,841 | 1,029 | 1,035 | 567 | 585 | 4,625 |
| 1979 | 9,006 | 1,089 | 1,158 | 718 | 680 | 5,361 |
| 1980 | 10,113 | 1,182 | 1,325 | 786 | 760 | 6,060 |
| 1981 | 11,423 | 1,302 | 1,614 | 863 | 825 | 6,819 |
| 1982 | 12,356 | 1,465 | 1,880 | 870 | 865 | 7,276 |
| 1983 | 13,596 | 1,690 | 2,171 | 983 | 945 | 7,807 |
| 1984 | 14,941 | 1,861 | 2,515 | 1,052 | 1,010 | 8,503 |
| 1985 | 16,349 | 1,961 | 2,731 | 1,078 | 1,075 | 9,504 |
| 1986 (Est.) | 17,809 | 2,000 | 2,959 | 1,150 | 1,100 | 10,600 |
| 1987 (Est.) | 18,595 | 2,000 | 3,125 | 1,200 | 1,120 | 11,150 |
| | Millions of constant 1982 dollars[1] | | | | | |
| 1960 | 4,556 | 517 | 1,215 | 313 | 423 | 2,087 |
| 1961 | 5,211 | 659 | 1,264 | 368 | 477 | 2,442 |
| 1962 | 6,165 | 786 | 1,528 | 426 | 595 | 2,830 |
| 1963 | 6,889 | 787 | 1,611 | 491 | 664 | 3,336 |
| 1964 | 7,777 | 954 | 1,667 | 580 | 705 | 3,872 |
| 1965 | 8,558 | 1,078 | 1,753 | 616 | 749 | 4,364 |
| 1966 | 9,228 | 1,101 | 1,785 | 649 | 787 | 4,906 |
| 1967 | 9,794 | 1,210 | 1,750 | 696 | 793 | 5,345 |
| 1968 | 10,061 | 1,145 | 1,702 | 732 | 787 | 5,696 |
| 1969 | 9,942 | 1,337 | 1,554 | 691 | 767 | 5,593 |
| 1970 | 9,726 | 1,373 | 1,432 | 640 | 726 | 5,556 |
| 1971 | 9,594 | 1,320 | 1,329 | 586 | 726 | 5,633 |
| 1972 | 9,544 | 1,344 | 1,276 | 525 | 742 | 5,657 |
| 1973 | 9,643 | 1,227 | 1,274 | 600 | 721 | 5,822 |
| 1974 | 9,466 | 1,290 | 1,295 | 528 | 751 | 5,602 |
| 1975 | 9,454 | 1,238 | 1,231 | 521 | 717 | 5,748 |
| 1976 | 9,762 | 1,246 | 1,299 | 569 | 736 | 5,912 |
| 1977 | 10,113 | 1,359 | 1,354 | 598 | 758 | 6,045 |
| 1978 | 10,857 | 1,425 | 1,433 | 785 | 810 | 6,404 |
| 1979 | 11,462 | 1,386 | 1,474 | 914 | 865 | 6,823 |
| 1980 | 11,798 | 1,379 | 1,546 | 917 | 887 | 7,070 |
| 1981 | 12,157 | 1,386 | 1,718 | 918 | 878 | 7,257 |
| 1982 | 12,356 | 1,465 | 1,880 | 870 | 865 | 7,276 |
| 1983 | 13,091 | 1,627 | 2,090 | 946 | 910 | 7,517 |
| 1984 | 13,869 | 1,727 | 2,335 | 977 | 938 | 7,893 |
| 1985 | 14,706 | 1,764 | 2,457 | 970 | 967 | 8,549 |
| 1986 (Est.) | 15,615 | 1,754 | 2,594 | 1,008 | 964 | 9,294 |
| 1987 (Est.) | 15,777 | 1,697 | 2,651 | 1,018 | 950 | 9,460 |

(continued)

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## Appendix table 5-1 (continued)

| Year | Total | Nonacademic basic research: Federal government | Industry | FFRDC's | Nonprofit institutions | Academic research and development |
|---|---|---|---|---|---|---|
| | Percent | | | | | |
| 1960 | 100.0 | 11.3 | 26.7 | 6.9 | 9.3 | 45.8 |
| 1961 | 100.0 | 12.7 | 24.3 | 7.1 | 9.2 | 46.9 |
| 1962 | 100.0 | 12.7 | 24.8 | 6.9 | 9.6 | 45.9 |
| 1963 | 100.0 | 11.4 | 23.4 | 7.1 | 9.6 | 48.4 |
| 1964 | 100.0 | 12.3 | 21.4 | 7.5 | 9.1 | 49.8 |
| 1965 | 100.0 | 12.6 | 20.5 | 7.2 | 8.8 | 51.0 |
| 1966 | 100.0 | 11.9 | 19.3 | 7.0 | 8.5 | 53.2 |
| 1967 | 100.0 | 12.4 | 17.9 | 7.1 | 8.1 | 54.6 |
| 1968 | 100.0 | 11.4 | 16.9 | 7.3 | 7.8 | 56.6 |
| 1969 | 100.0 | 13.5 | 15.6 | 7.0 | 7.7 | 56.3 |
| 1970 | 100.0 | 14.1 | 14.7 | 6.6 | 7.5 | 57.1 |
| 1971 | 100.0 | 13.8 | 13.9 | 6.1 | 7.6 | 58.7 |
| 1972 | 100.0 | 14.1 | 13.4 | 5.5 | 7.8 | 59.3 |
| 1973 | 100.0 | 12.7 | 13.2 | 6.2 | 7.5 | 60.4 |
| 1974 | 100.0 | 13.6 | 13.7 | 5.6 | 7.9 | 59.2 |
| 1975 | 100.0 | 13.1 | 13.0 | 5.5 | 7.6 | 60.8 |
| 1976 | 100.0 | 12.8 | 13.3 | 5.8 | 7.5 | 60.6 |
| 1977 | 100.0 | 13.4 | 13.4 | 5.9 | 7.5 | 59.8 |
| 1978 | 100.0 | 13.1 | 13.2 | 7.2 | 7.5 | 59.0 |
| 1979 | 100.0 | 12.1 | 12.9 | 8.0 | 7.6 | 59.5 |
| 1980 | 100.0 | 11.7 | 13.1 | 7.8 | 7.5 | 59.9 |
| 1981 | 100.0 | 11.4 | 14.1 | 7.6 | 7.2 | 59.7 |
| 1982 | 100.0 | 11.9 | 15.2 | 7.0 | 7.0 | 58.9 |
| 1983 | 100.0 | 12.4 | 16.0 | 7.2 | 7.0 | 57.4 |
| 1984 | 100.0 | 12.5 | 16.8 | 7.0 | 6.8 | 56.9 |
| 1985 | 100.0 | 12.0 | 16.7 | 6.6 | 6.6 | 58.1 |
| 1986 (Est.) | 100.0 | 11.2 | 16.6 | 6.5 | 6.2 | 59.5 |
| 1987 (Est.) | 100.0 | 10.8 | 16.8 | 6.5 | 6.0 | 60.0 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

Science & Engineering Indicators—1987

## Appendix table 5-2. Basic research expenditures by performer, for selected countries

| Performer | United States | Japan | Germany[1] | France[1] | United Kingdom |
|---|---|---|---|---|---|
| | Percent | | | | |
| Total | 100 | 100 | 100 | 100 | 100 |
| Higher education | 57 | 61 | 60 | 67 | 55 |
| Industry | 19 | 26 | 18 | 9 | 13 |
| Government[2] | 16 | 11 | 22 | 22 | 30 |
| Private nonprofit | 8 | 2 | 1 | 3 | 2 |

Note: Data is for a year in the 1980-84 period depending upon the country. Data for Japan, West Germany and France include the natural sciences and engineering, the social sciences and the humanities; the United States data exclude the humanities; the U.K. data excludes the social sciences and the humanities

[1] In France, CNRS R&D is classified as higher education in performance data but as government in source-of-funds data; in West Germany the Max Planck Institutes are classified as government.

[2] In the U.S., the government sector is federal only; in other countries, government includes all levels.

SOURCE: National Science Foundation; Organisation for Economic Co-operation and Development (OECD), and unpublished estimates

See figure 5-1.

Science & Engineering Indicators—1987

## Appendix table 5-3. Scientists and engineers in academic research and development and basic research:[1] 1986

| Field | Business & industry | | Education | | Nonprofit | | Federal Government[2] | | All institutions | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Total | 13,100 | 6.1 | 168,900 | 79.2 | 9,400 | 4.4 | 17,200 | 8.1 | 213,300 | 100.0 |
| Total scientists | 9,400 | 5.4 | 138,300 | 78.7 | .100 | 5.2 | 14,500 | 8.3 | 175,700 | 100.0 |
| Physical scientists | 3,900 | 12.0 | 20,400 | 62.8 | 1,200 | 3.7 | 5,600 | 17.2 | 32,500 | 100.0 |
| Chemists | 2,400 | 17.3 | 9,400 | 67.6 | 200 | 1.4 | 1,600 | 11.5 | 13,900 | 100.0 |
| Physicists/astronomers | 1,400 | 8.8 | 9,600 | 60.4 | 1,000 | 6.3 | 3,000 | 18.9 | 15,900 | 100.0 |
| Other physical scientists | 100 | 3.4 | 1,500 | 51.7 | NA | NA | 1,000 | 34.5 | 2,900 | 100.0 |
| Environmental scientists | 1,400 | 10.9 | 8,200 | 64.1 | 300 | 2.3 | 2,300 | 18.0 | 12,800 | 100.0 |
| Atmospheric scientists | NA | NA | 1,500 | 68.2 | 100 | 4.5 | 400 | 18.2 | 2,200 | 100.0 |
| Earth scientists | 1,200 | 13.8 | 5,100 | 58.6 | NA | NA | 1,900 | 21.8 | 8,700 | 100.0 |
| Oceanographers | NA | NA | 1,600 | 84.2 | 300 | 15.8 | 100 | 5.3 | 1,900 | 100.0 |
| Mathematical scientists | 100 | 1.4 | 5,300 | 72.6 | NA | NA | 200 | 2.7 | 7,300 | 100.0 |
| Computer specialists | 500 | 6.9 | 6,200 | 86.1 | 300 | 4.2 | 200 | 2.8 | 7,200 | 100.0 |
| Life scientists | 2,300 | 2.7 | 67,800 | 80.8 | 6,400 | 7.6 | 5,500 | 6.6 | 83,900 | 100.0 |
| Agricultural scientists | 200 | 1.4 | 13,500 | 91.2 | NA | NA | 900 | 6.1 | 14,800 | 100.0 |
| Biological scientists | 2,100 | 3.6 | 45,100 | 76.7 | 5,600 | 9.5 | 4,400 | 7.5 | 58,800 | 100.0 |
| Medical scientists | NA | NA | 9,200 | 89.3 | 900 | 8.7 | 200 | 1.9 | 10,300 | 100.0 |
| Psychologists | 400 | 3.2 | 11,400 | 90.5 | 400 | NA | 200 | 1.6 | 12,600 | 100.0 |
| Social scientists | 900 | 4.6 | 17,400 | 89.2 | 400 | 2.1 | 500 | 2.6 | 19,500 | 100.0 |
| Economists | 400 | 4.8 | 7,300 | 88.0 | 300 | 3.6 | 300 | 3.6 | 8,300 | 100.0 |
| Sociologists/anthropologists | 400 | 6.6 | 5,200 | 85.2 | 100 | 1.6 | 100 | 1.6 | 6,100 | 100.0 |
| Other social scientists | NA | NA | 5,000 | 98.0 | NA | NA | NA | NA | 5,100 | 100.0 |
| Total engineers | 3,700 | 9.8 | 30,600 | 81.0 | 200 | 0.5 | 2,700 | 7.1 | 37,800 | 100.0 |
| Aeronautical and astronautical | 300 | 11.1 | 1,400 | 51.9 | NA | NA | 1,000 | 37.0 | 2,700 | 100.0 |
| Chemical | 500 | 18.2 | 2,600 | 78.8 | 100 | 3.0 | NA | NA | 3,300 | 100.0 |
| Civil | 300 | 9.7 | 2,300 | 74.2 | NA | NA | 200 | NA | 3,100 | 100.0 |
| Electrical/electronics | 700 | 6.5 | 9,200 | 85.2 | 200 | NA | 600 | 5.6 | 10,800 | 100.0 |
| Industrial | 100 | 14.3 | 600 | 85.7 | NA | NA | NA | NA | 700 | 100.0 |
| Materials | 300 | 13.0 | 1,900 | 82.6 | NA | NA | NA | NA | 2,300 | 100.0 |
| Mechanical | 900 | 13.2 | 5,700 | 83.8 | NA | NA | 200 | 2.9 | 6,800 | 100.0 |
| Mining | NA | NA | 200 | 66.7 | NA | NA | NA | NA | 300 | 100.0 |
| Nuclear | NA | NA | 400 | 100.0 | NA | NA | 100 | 25.0 | 400 | 100.0 |
| Petroleum | NA | NA | 300 | 75.0 | NA | NA | NA | NA | 400 | 100.0 |
| Other engineers | 500 | 7.1 | 6,100 | 87.1 | NA | NA | 300 | 4.3 | 7,000 | 100.0 |

Note: NA - Not available.

[1] Data include S/E's whose primary work activity is basic research or, in educational institutions, research and development

[2] S/E's whose primary work activity is military have been included with Federal Government

SOURCE: National Science Foundation, Surveys of Science Resources Series, *U.S. Scientists and Engineers, 1986*

See figures 5-2 and 5-5.

Appendix table 5-4. Ph.D. scientists and engineers in academic research and development and basic research:[1] 1985

| Field | Business & industry | | Education | | Nonprofit | | Federal Government[2] | | All institutions | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Total | 6,820 | 8.7 | 60,739 | 77.3 | 3,447 | 4.4 | 6,293 | 8.0 | 78,570 | 100.0 |
| Total scientists | 6,211 | 8.6 | 55,550 | 76.9 | 3,392 | 4.7 | 5,726 | 7.9 | 72,200 | 100.0 |
| Physical scientists | 3,377 | 20.7 | 10,695 | 65.4 | 843 | 5.2 | 1,357 | 8.3 | 16,341 | 100.0 |
| Chemists | 2,520 | 29.7 | 5,072 | 59.9 | 225 | 2.7 | 605 | 7.1 | 8,474 | 100.0 |
| Physicists/astronomers | 857 | 10.9 | 5,623 | 71.5 | 618 | 7.9 | 752 | 9.6 | 7,867 | 100.0 |
| Environmental scientists | 341 | 7.9 | 2,701 | 62.5 | 290 | 6.7 | 927 | 21.5 | 4,320 | 100.0 |
| Atmospheric scientists | 45 | 4.7 | 608 | 63.1 | 144 | 15.0 | 161 | 16.7 | 963 | 100.0 |
| Earth scientists | 263 | 11.3 | 1,335 | 57.2 | 78 | 3.3 | 604 | 25.9 | 2,334 | 100.0 |
| Oceanographers | 33 | 3.2 | 758 | 74.1 | 68 | 6.6 | 162 | 15.8 | 1,023 | 100.0 |
| Mathematical scientists | 154 | 5.9 | 2,396 | 91.1 | 44 | 1.7 | 36 | 1.4 | 2,630 | 100.0 |
| Computer specialists | 180 | 10.6 | 1,438 | 84.6 | 10 | 0.6 | 71 | 4.2 | 1,699 | 100.0 |
| Life scientists | 2,064 | 5.5 | 29,150 | 78.0 | 1,951 | 5.2 | 3,199 | 8.6 | 37,372 | 100.0 |
| Agricultural scientists | 101 | 2.0 | 4,271 | 84.8 | 53 | 1.1 | 552 | 11.0 | 5,034 | 100.0 |
| Biological scientists | 1,666 | 6.3 | 20,017 | 75.3 | 1,854 | 7.0 | 2,422 | 9.1 | 26,600 | 100.0 |
| Medical scientists | 297 | 5.2 | 4,862 | 84.7 | 179 | 3.1 | 225 | 3.9 | 5,738 | 100.0 |
| Psychologists | 55 | 1.4 | 3,607 | 93.7 | 89 | 2.3 | 56 | 1.5 | 3,849 | 100.0 |
| Social scientists | 40 | 0.7 | 5,563 | 93.7 | 165 | 2.8 | 80 | 1.3 | 5,939 | 100.0 |
| Economists | 10 | 0.4 | 2,344 | 99.3 | 0 | 0.0 | 7 | 0.3 | 2,361 | 100.0 |
| Sociologists/anthropologists | 3 | 0.2 | 1,336 | 95.6 | 54 | 3.9 | 0 | 0.0 | 1,398 | 100.0 |
| Other social scientists | 27 | 1.2 | 1,883 | 86.4 | 111 | 5.1 | 73 | 3.3 | 2,180 | 100.0 |
| Total engineers | 609 | 9.5 | 5,189 | 80.8 | 55 | 0.9 | 567 | 8.8 | 6,420 | 100.0 |
| Aeronautical and astronautical | 16 | 3.9 | 252 | 61.5 | 2 | 0.5 | 140 | 34.1 | 410 | 100.0 |
| Chemical | 69 | 10.1 | 566 | 82.9 | 0 | 0.0 | 48 | 7.0 | 683 | 100.0 |
| Civil | 32 | 5.3 | 571 | 94.7 | 0 | 0.0 | 0 | 0.0 | 603 | 100.0 |
| Electrical/electronics | 108 | 12.1 | 781 | 87.9 | 0 | 0.0 | 0 | 0.0 | 889 | 100.0 |
| Materials | 166 | 18.9 | 488 | 55.5 | 48 | 5.5 | 177 | 20.1 | 879 | 100.0 |
| Mechanical | 24 | 3.5 | 619 | 90.4 | 0 | 0.0 | 42 | 6.1 | 685 | 100.0 |
| Nuclear | 28 | 9.6 | 263 | 90.4 | 0 | 0.0 | 0 | 0.0 | 291 | 100.0 |
| Systems design engineers | 16 | 8.0 | 178 | 89.4 | 5 | 2.5 | 0 | 0.0 | 199 | 100.0 |
| Other engineers | 150 | 8.4 | 1,471 | 82.6 | 0 | 0.0 | 160 | 9.0 | 1,781 | 100.0 |

[1] Data include S/E's whose primary work activity is basic research or, in educational institutions, research and development.

[2] S/E's whose primary work activity is military have been included with Federal Government.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 5-6.

Science & Engineering Indicators—1987

**Appendix table 5-5. Doctoral scientists and engineers in research,[1] by gender: 1975 and 1985**

| Sector | Total | Male | Female | Male | Female |
|---|---|---|---|---|---|
| | | | 1975 | | |
| | | | | — Percent — | |
| Total | 110,765 | 100,660 | 10,105 | 90.9 | 9.1 |
| 4-year universities and colleges | 99,226 | 90,182 | 9,044 | 90.9 | 9.1 |
| Business and industry | 4,273 | 4,024 | 249 | 94.2 | 5.8 |
| Other non-profit | 2,238 | 1,908 | 330 | 85.3 | 14.7 |
| Federal government | 4,679 | 4,267 | 412 | 91.2 | 8.8 |
| State and local governments | 349 | 279 | 70 | 79.9 | 20.1 |
| | | | 1985 | | |
| | | | | — Percent — | |
| Total | 137,608 | 117,458 | 20,150 | 85.4 | 14.6 |
| 4-year universities and colleges | 120,691 | 102,731 | 17,960 | 85.1 | 14.9 |
| Business and industry | 6,820 | 6,135 | 685 | 90.0 | 10.0 |
| Other non-profit | 3,447 | 2,736 | 711 | 79.4 | 20.6 |
| Federal government | 6,189 | 5,456 | 733 | 88.2 | 11.8 |
| State and local governments | 461 | 400 | 61 | 86.8 | 13.2 |

[1] Data include doctoral S/E's whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Academy of Sciences. Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-3. Science & Engineering Indicators—1987

**Appendix table 5-6. Doctoral scientists and engineers in research[1] by race and type of employer: 1975 and 1985**

| Sector | Total | White | Black | Asian | Other |
|---|---|---|---|---|---|
| | | | 1975 | | |
| Total | 110,765 | 100,524 | 874 | 6,310 | 3,057 |
| 4-year universities and colleges | 99,226 | 90,211 | 755 | 5,459 | 2,801 |
| Business and industry | 4,273 | 3,772 | 19 | 373 | 109 |
| Other non-profit | 2,238 | 1,920 | 13 | 239 | 66 |
| Federal government | 4,679 | 4,303 | 83 | 222 | 71 |
| State and local governments | 349 | 318 | 4 | 17 | 10 |
| | | | 1985 | | |
| Total | 137,147 | 122,602 | 1,606 | 12,331 | 1,069 |
| 4-year universities and colleges | 120,691 | 107,809 | 1,466 | 10,522 | 894 |
| Business and industry | 6,820 | 5,786 | 64 | 888 | 82 |
| Other non-profit | 3,447 | 2,954 | 6 | 457 | 30 |
| Federal government | 6,189 | 5,594 | 70 | 462 | 63 |
| State and local governments | NA | 459 | NA | 2 | NA |

[1] Data include doctoral S/E's whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Academy of Sciences. Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-4. Science & Engineering Indicators—1987

Appendix table 5-7. Foreign recipients of U.S. doctoral degrees[1] with postgraduation plans, by field of science: 1972 & 1986

| Fields | Total | Doctorate recipients with firm plans | | | Doctorate recipients with firm plans in U.S. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Employment | | |
| | | Total | U.S. | Abroad | Study[2] | Academic | Industrial | Other |
| | Doctoral recipients — 1972 | | | | | | | |
| Total science/engineering fields | 2,169 | 1,397 | 408 | 989 | 251 | 94 | 30 | 30 |
| Physical sciences | 387 | 240 | 105 | 135 | 94 | 6 | 4 | 0 |
| Physics/astronomy | 209 | 132 | 64 | 68 | 56 | 4 | 3 | 0 |
| Chemistry | 178 | 108 | 41 | 67 | [illegible] | 2 | 1 | 0 |
| Earth, environmental & marine sciences | 64 | 43 | 10 | 33 | 4 | 3 | 1 | 2 |
| Mathematical sciences | 169 | 102 | 42 | 60 | 16 | 22 | 2 | 2 |
| Computer science | NA | NA | NA | NA | NA | NA | NA | NA |
| Life sciences | 537 | 359 | 83 | 276 | 71 | 7 | 2 | 1 |
| Biological sciences | 305 | 205 | 70 | 135 | 61 | 5 | 1 | 1 |
| Agricultural sciences | 232 | 154 | 13 | 141 | 10 | 2 | 1 | 0 |
| Social sciences | 415 | 314 | 62 | 252 | 9 | 33 | 0 | 20 |
| Psychology | 78 | 48 | 13 | 35 | 2 | 9 | 1 | 1 |
| Engineering | 519 | 291 | 93 | 198 | 55 | 14 | 20 | 4 |
| | Doctoral recipients — 1986 | | | | | | | |
| Total science/engineering fields | 4,051 | 2,617 | 1,371 | 1,040 | 744 | 365 | 233 | 29 |
| Physical sciences | 758 | 497 | 344 | 109 | 294 | 23 | 24 | 3 |
| Physics/astronomy | 365 | 248 | 165 | 63 | 137 | 12 | 15 | 1 |
| Chemistry | 393 | 249 | 179 | 46 | 157 | 11 | 9 | 2 |
| Earth, environmental & marine sciences | 106 | 71 | 32 | 37 | 24 | 4 | 3 | 1 |
| Mathematical sciences | 272 | 194 | 123 | 54 | 48 | 71 | 3 | 1 |
| Computer science | 122 | 84 | 59 | 22 | 9 | 31 | 18 | 1 |
| Life sciences | 711 | 493 | 187 | 272 | 162 | 14 | 9 | 2 |
| Biological sciences | 391 | 275 | 146 | 108 | 132 | 9 | 3 | 2 |
| Agricultural sciences | 320 | 218 | 41 | 164 | 30 | 5 | 6 | 0 |
| Social sciences | 633 | 414 | 115 | 268 | 18 | 85 | 4 | 3 |
| Psychology | 80 | 44 | 16 | 25 | 8 | 7 | 0 | 1 |
| Engineering | 1,369 | 820 | 495 | 253 | 181 | 130 | 172 | 12 |
| | Percent of all foreign recipients with firm plans — 1972 | | | | | | | |
| Total science/engineering fields | | 100 | 29.2 | 70.8 | 18.0 | 6.7 | 2.1 | 2.1 |
| Physical sciences | | 100 | 43.8 | 56.3 | 39.2 | 2.5 | 1.7 | 0.0 |
| Physics/astronomy | | 100 | 48.5 | 51.5 | 42.4 | 3.0 | 2.3 | 0.0 |
| Chemistry | | 100 | 38.0 | 62.0 | 35.2 | 1.9 | 0.9 | 0.0 |
| Earth, environmental & marine sciences | | 100 | 23.3 | 76.7 | 9.3 | 7.0 | 2.3 | 4.7 |
| Mathematical sciences | | 100 | 41.2 | 58.8 | 15.7 | 21.6 | 2.0 | 2.0 |
| Computer science | | NA | NA | NA | NA | NA | NA | NA |
| Life sciences | | 100 | 23.1 | 76.9 | 19.8 | 1.9 | 0.6 | 0.3 |
| Biological sciences | | 100 | 34.1 | 65.9 | 29.8 | 2.4 | 0.5 | 0.5 |
| Agricultural sciences | | 100 | 8.4 | 91.6 | 6.5 | 1.3 | 0.6 | 0.0 |
| Social sciences | | 100 | 19.7 | 80.3 | 2.9 | 10.5 | 0.0 | 6.4 |
| Psychology | | 100 | 27.1 | 72.9 | 4.2 | 18.3 | 2.1 | 2.1 |
| Engineering | | 100 | 32.0 | 68.0 | 18.9 | 4.8 | 6.9 | 1.4 |
| | Percent of all foreign recipients with firm plans—1986 | | | | | | | |
| Total science/engineering fields | | 100 | 52.4 | 39.7 | 28.4 | 13.9 | 8.9 | 1.1 |
| Physical sciences | | 100 | 69.2 | 21.9 | 59.2 | 4.6 | 4.8 | 0.6 |
| Physics/astronomy | | 100 | 66.5 | 25.4 | 55.2 | 4.8 | 6.0 | 0.4 |
| Chemistry | | 100 | 71.9 | 18.5 | 63.1 | 4.4 | 3.6 | 0.8 |
| Earth, environmental & marine sciences | | 100 | 45.[illegible] | 52.1 | 33.8 | 5.6 | 4.2 | 1.4 |
| Mathematical sciences | | 100 | 63.4 | 27.8 | 24.7 | 36.6 | 1.5 | 0.5 |
| Computer science | | 100 | 70.2 | 26.2 | 10.7 | 36.9 | 21.4 | 1.2 |
| Life sciences | | 100 | 37.9 | 55.2 | 32.9 | 2.8 | 1.8 | 0.4 |
| Biological sciences | | 100 | 53.1 | 39.3 | 48.0 | 3.3 | 1.1 | 0.7 |
| Agricultural sciences | | 100 | 18.8 | 75.2 | 13.8 | 2.3 | 2.8 | 0.0 |
| Social sciences | | 100 | 27.8 | 64.7 | 4.3 | 20.5 | 1.0 | 1.9 |
| Psychology | | 100 | 36.4 | 56.8 | 18.2 | 15.9 | 0.0 | 2.3 |
| Engineering | | 100 | 60.4 | 30.9 | 22.1 | 15.9 | 21.0 | 1.5 |

Note: NA - not available

[1] Excludes foreign doctorate recipients holding U.S. permanent residence visas

[2] Includes postdoctoral research assistants.

SOURCE: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File, special tabulations

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## Appendix table 5-8. Proportion of Ph.D. researchers[1] who remained employed in sector: 1973-85

| Years[2] | Employment sectors: Business and industry | 4 year colleges and universities | Nonprofit institutions | Federal Government |
|---|---|---|---|---|
| | Percent | | | |
| All fields: | | | | |
| 1973-75 | 96.0 | 96.4 | 67.3 | 82.2 |
| 1975-77 | 96.4 | 95.4 | 76.4 | 90.3 |
| 1977-79 | 95.5 | 94.3 | 78.5 | 91.8 |
| 1979-81 | 96.5 | 95.2 | 77.3 | 93.0 |
| 1981-83 | 95.4 | 94.8 | 66.6 | 93.3 |
| 1983-85 | 96.5 | 95.6 | 75.5 | 89.3 |
| Scientists: | | | | |
| 1973-75 | 96.2 | 96.4 | 68.6 | 82.4 |
| 1975-77 | 96.8 | 95.3 | 73.8 | 89.7 |
| 1977-79 | 95.0 | 94.6 | 78.4 | 92.2 |
| 1979-81 | 96.1 | 95.3 | 73.6 | 92.9 |
| 1981-83 | 96.1 | 94.7 | 67.1 | 93.0 |
| 1983-85 | 95.8 | 95.4 | 74.2 | 89.6 |
| Engineers: | | | | |
| 1973-75 | 95.5 | 95.8 | 60.3 | 81.1 |
| 1975-77 | 95.5 | 96.8 | 94.5 | 95.0 |
| 1977-79 | 96.9 | 91.9 | 79.8 | 88.3 |
| 1979-81 | 97.7 | 94.2 | 93.2 | 93.8 |
| 1981-83 | 93.9 | 96.2 | 64.6 | 97.2 |
| 1983-85 | 98.1 | 96.9 | 82.8 | 87.5 |

[1] Data include doctoral S/E's whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

[2] The survey instrument is collected biennially. The proportions shown are those giving the same answer to the sector-of-employment question in the second year of the range as they did in the first year.

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-9.

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## Appendix table 5-9. Scientists and engineers in academic research and development and basic research:[1] 1976-1986

| Field | 1976 | 1973 | 1980 | 1982 | 1984 | 1986 |
|---|---|---|---|---|---|---|
| Total | 92,900 | 105,900 | 127,200 | 150,500 | 188,200 | 213,300 |
| Total scientists | 79,200 | 93.800 | 110,600 | 129,400 | 156,300 | 175,700 |
| Physical scientists | 21,700 | 23,600 | 24,900 | 26,800 | 27,400 | 32,500 |
| Chemists | 9,500 | 10,200 | 11,300 | 12,300 | 11,900 | 13,900 |
| Physicists/astronomers | 10,700 | 10,700 | 10,800 | 10,800 | 12,700 | 15,900 |
| Other physical scientists | 1,600 | 2,800 | 2.700 | 3,600 | 2,900 | 2,900 |
| Environmental scientists | 6,700 | 6,800 | 7,800 | 9,100 | 12,400 | 12,800 |
| Atmospheric scientists | 1,300 | 1,900 | 1,900 | 2,500 | 3,100 | 2,200 |
| Earth scientists | 5,300 | 3,300 | 4,300 | 5,300 | 8,300 | 8,700 |
| Oceanographers | 200 | 1,700 | 1,600 | 1,400 | 1,000 | 1,900 |
| Mathematical scientists | 2,300 | 3,000 | 3,500 | 4,000 | 5,300 | 7,300 |
| Computer specialists | 1,200 | 2,200 | 2,300 | 2,800 | 6,000 | 7,200 |
| Life scientists | 33,400 | 44,600 | 55,600 | 66,800 | 74,300 | 83.900 |
| Agricultural scientists | 4,700 | 6,600 | 8,200 | 10,500 | 12,000 | 14,800 |
| Biological scientists | 23,400 | 28,900 | 38,300 | 47,600 | 53,700 | 58,800 |
| Medical scientists | 5,500 | 9,300 | 9,200 | 8,600 | 8,600 | 10,300 |
| Psychologists | 4,000 | 4,900 | 6,000 | 6,300 | 10,900 | 12,600 |
| Social scientists | 9,900 | 8,700 | 10,500 | 13,600 | 20,300 | 19,500 |
| Economists | 2,100 | 2,000 | 3,200 | 5,300 | 7,900 | 8,300 |
| Sociologists/anthropologists | 4,300 | 3,300 | 4,600 | 5,300 | 5,200 | 6,100 |
| Other social scientists | 3,500 | 2,900 | 2,700 | 3,000 | 7,100 | 5,100 |
| Total engineers | 13,600 | 12,000 | 16,500 | 21,100 | 31,800 | 37,800 |
| Aeronautical and astronautical | 1,200 | 400 | 900 | NA | NA | 2,700 |
| Chemical | 500 | 700 | 1,200 | 1,400 | 2,200 | 3,300 |
| Civil | 1,800 | 1,000 | 1,500 | 1,500 | 2,500 | 3,100 |
| Electrical/electronics | 3.300 | 3,500 | 4,800 | 7,000 | 8,400 | 10,800 |
| Industrial | NA | NA | NA | 400 | 500 | 700 |
| Materials | NA | NA | NA | 1,300 | 2,500 | 2,300 |
| Mechanical | 2,300 | 1,800 | 2,400 | 3,200 | 6,700 | 6,800 |
| Mining | NA | NA | NA | 300 | 500 | 300 |
| Nuclear | NA | NA | NA | 400 | 500 | 400 |
| Petroleum | NA | NA | NA | 400 | NA | 400 |
| Other engineers | 4,300 | 4,600 | 5,900 | 4,000 | 6,500 | 7,000 |

Note: NA = Not available.

[1] Includes scientists and engineers whose primary work activity is basic research or, in 4-year colleges and universities, research and development

SOURCE: National Science Foundation, *U.S. Scientists and Engineers, 1986*

See figure 5-7.



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**Appendix table 5-10. Ph.D. scientists and engineers in academic research and development and basic research:[1] 1977-1985**

| Field | 1977 | 1979 | 1981 | 1983 | 1985 |
|---|---|---|---|---|---|
| Total | 56,123 | 61,468 | 70,004 | 72,329 | 78,570 |
| Total scientists | 51,926 | 56,767 | 64,694 | 66,245 | 72,200 |
| Physical scientists | 13,887 | 13,973 | 15,818 | 15,873 | 16,341 |
| Chemists | 7,558 | 7,413 | 8,686 | 8,242 | 8,474 |
| Physicists/astronomers | 6,329 | 6,560 | 7,132 | 7,631 | 7,867 |
| Environmental scientists | 3,021 | 3,341 | 4,024 | 3,851 | 4,320 |
| Atmospheric scientists | 569 | 730 | 812 | 871 | 963 |
| Earth scientists | 1,788 | 1,935 | 2,279 | 2,119 | 2,334 |
| Oceanographers | 664 | 676 | 933 | 861 | 1,023 |
| Mathematical scientists | 2,154 | 2,447 | 2,121 | 2,159 | 2,630 |
| Computer specialists | 598 | 756 | 1,061 | 1,165 | 1,699 |
| Life scientists | 24,706 | 28,383 | 33,530 | 34,238 | 37,372 |
| Agricultural scientists | 3,749 | 3,921 | 4,719 | 4,382 | 5,034 |
| Biological scientists | 17,149 | 19,451 | 22,888 | 24,664 | 26,600 |
| Medical scientists | 3,808 | 5,011 | 5,923 | 5,192 | 5,738 |
| Psychologists | 2,848 | 3,599 | 3,649 | 3,439 | 3,849 |
| Social scientists | 4,712 | 4,268 | 4,491 | 5,520 | 5,939 |
| Economists | 1,216 | 1,217 | 1,321 | 2,051 | 2,361 |
| Sociologists/anthropologists | 1,386 | 1,331 | 1,422 | 1,553 | 1,398 |
| Other social scientists | 2,110 | 1,720 | 1,748 | 1,916 | 2,180 |
| Total engineers | 4,197 | 4,701 | 5,310 | 6,084 | 6,420 |
| Aeronautical and astronautical | NA | NA | 316 | 451 | 410 |
| Chemical | NA | NA | 433 | 492 | 683 |
| Civil | NA | NA | 445 | 492 | 603 |
| Electrical/electronics | NA | NA | 700 | 822 | 889 |
| Materials | NA | NA | 735 | 1,180 | 879 |
| Mechanical | NA | NA | 540 | 345 | 685 |
| Nuclear | NA | NA | 299 | 339 | 291 |
| Systems design | NA | NA | 358 | 203 | 199 |
| Other engineers | NA | NA | 1,484 | 1,760 | 1,781 |

Note: NA = Not available.

[1] Includes scientists and engineers whose primary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 5-8.

## Appendix table 5-11. Proportion of Ph.D. researchers employed in nonprofits and government who moved to other sectors: 1973-85

| Year[2] and field | Mobility from nonprofits to: | | | Mobility from government to: | | |
|---|---|---|---|---|---|---|
| | Business and industry | Colleges and universities | Federal Government | Business and industry | Colleges and universities | Nonprofit institutions |
| | Percent | | | | | |
| All fields: | | | | | | |
| 1973-75 | 5.4 | 22.1 | 3.8 | 3 | 10.6 | 1.8 |
| 1975-77 | 3.6 | 14.1 | 2.5 | 1.8 | 4 | 2 |
| 1977-79 | 4.7 | 12.9 | 1.3 | 0.9 | 3.3 | 1.3 |
| 1979-81 | 4.0 | 10.6 | 6.5 | 2.4 | 2.8 | 0.3 |
| 1981-83 | 18.5 | 11.4 | 1.5 | 3 | 2.4 | 0.5 |
| 1983-85 | 10.4 | 11.3 | 1.4 | 2 | 4.9 | 1.4 |
| Scientists: | | | | | | |
| 1973-75 | 4.9 | 21.4 | 3.8 | 2.7 | 10.4 | 1.7 |
| 1975-77 | 3.7 | 16.1 | 2.5 | 1.7 | 4.2 | 2.3 |
| 1977-79 | 3.6 | 13.7 | 1.4 | 1 | 3.7 | 0.9 |
| 1979-81 | 4.9 | 11.6 | 8.0 | 2.4 | 2.7 | 0.3 |
| 1981-83 | 15.0 | 13.6 | 1.9 | 3.3 | 2.5 | 0.5 |
| 1983-85 | 9.6 | 12.9 | 1.6 | 1.7 | 5 | 0.5 |
| Engineers: | | | | | | |
| 1973-75 | 8.3 | 25.9 | NA | 4.6 | 11.9 | 2.4 |
| 1975-77 | 2.8 | NA | NA | 2.3 | 2.7 | NA |
| 1977-79 | 13.9 | 6.4 | 0.2 | NA | NA | 5.2 |
| 1979-81 | NA | 6.5 | NA | 1.9 | 3.6 | 0.6 |
| 1981-83 | 0.8 | 1.5 | 2.8 | NA | 1.4 | 1.4 |
| 1983-85 | 15.2 | 1.9 | 3.7 | 4.4 | 4.7 | 3.3 |

[1] Data include doctoral S/E's whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development

[2] The survey data are collected biennially.

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

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## Appendix table 5-12. Proportion of Ph.D. researchers[1] who moved between university and industry: 1973-85

| Year[2] and field | From universities and colleges to business and industry | From business and industry to universities and colleges |
|---|---|---|
| | Percent | |
| All fields: | | |
| 1973-75 | 1.7 | 1.8 |
| 1975-77 | 1.8 | 2.1 |
| 1977-79 | 2.4 | 2.3 |
| 1979-81 | 2.5 | 2.1 |
| 1981-83 | 2.8 | 2.8 |
| 1983-85 | 2.3 | 1.6 |
| Scientists: | | |
| 1973-75 | 1.7 | 1.8 |
| 1975-77 | 1.8 | 2.0 |
| 1977-79 | 2.2 | 2.0 |
| 1979-81 | 2.5 | 2.1 |
| 1981-83 | 2.8 | 2.1 |
| 1983-85 | 2.3 | 2.2 |
| Engineers: | | |
| 1973-75 | 2.4 | 2.8 |
| 1975-77 | 2.3 | 2.4 |
| 1977-79 | 4.4 | 3.1 |
| 1979-81 | 3.4 | 2.2 |
| 1981-83 | 2.6 | 4.4 |
| 1983-85 | 1.6 | 0.1 |

[1] Doctoral S/E's in industry whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

[2] The survey data are collected biennially.

SOURCE: National Academy of Sciences, *Survey of Doctoral Recipients* (special tabulations prepared for the National Science Foundation, 1986)

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## Appendix table 5-13. Cross-sectoral institutional coauthorship: 1973, 1977, 1981, and 1984

| Sectors[2] | Articles[1] | | | | Percent | | | |
|---|---|---|---|---|---|---|---|---|
| | 1973 | 1977 | 1981 | 1984 | 1973 | 1977 | 1981 | 1984 |
| **Participation in industry articles:** | | | | | | | | |
| University | 1,603 | 1,631 | 2,310 | 2,877 | 13.1 | 15.3 | 20.1 | 24.3 |
| Nonprofit | 164 | 140 | 225 | 351 | 1.3 | 1.3 | 2.0 | 3.0 |
| FFRDC's | 106 | 133 | 199 | 309 | 0.9 | 1.2 | 1.7 | 2.6 |
| Government | 433 | 463 | 563 | 762 | 3.5 | 4.4 | 4.9 | 6.4 |
| **Participation in nonprofit articles:** | | | | | | | | |
| University | 4,570 | 4,689 | 5,831 | 6,093 | 45.3 | 47.9 | 51.3 | 53.0 |
| Industry | 164 | 140 | 225 | 351 | 1.6 | 1.4 | 2.0 | 3.1 |
| FFRDC's | 38 | 48 | 75 | 104 | 0.4 | 0.5 | 0.7 | 0.9 |
| Government | 716 | 743 | 876 | 857 | 7.1 | 7.6 | 7.7 | 7.5 |
| **Participation in FFRDC articles:** | | | | | | | | |
| University | 1,408 | 1,485 | 1,811 | 1,879 | 29.7 | 31.3 | 32.5 | 37.3 |
| Industry | 106 | 133 | 199 | 309 | 2.2 | 2.8 | 3.6 | 6.1 |
| Nonprofits | 38 | 48 | 75 | 104 | 0.8 | 1.0 | 1.3 | 2.1 |
| Government | 110 | 136 | 208 | 263 | 2.3 | 2.9 | 3.7 | 5.2 |
| **Participation in Federal Government articles:** | | | | | | | | |
| University | 6,372 | 6,816 | 7,957 | 8,228 | 35.0 | 40.8 | 45.4 | 47.6 |
| Industry | 433 | 463 | 563 | 762 | 2.4 | 2.8 | 3.2 | 4.4 |
| Nonprofits | 716 | 743 | 876 | 857 | 3.9 | 4.4 | 5.0 | 5.0 |
| FFRDC's | 110 | 136 | 208 | 263 | 0.6 | 0.8 | 1.2 | 1.5 |
| **Participation in university articles:** | | | | | | | | |
| Industry | 1,603 | 1,631 | 2,310 | 2,877 | 2.0 | 2.1 | 2.8 | 3.4 |
| Nonprofits | 4,570 | 4,689 | 5,831 | 6,093 | 5.7 | 6.0 | 6.9 | 7.2 |
| FFRDC's | 1,408 | 1,485 | 1,811 | 1,879 | 1.7 | 1.9 | 2.2 | 2.2 |
| Government | 6,372 | 6,816 | 7,957 | 8,228 | 7.9 | 8.7 | 9.5 | 9.8 |

Note. One cross-sectoral institutional coauthorship is counted when an article with an author from one sector also lists an author from another sector For example, in 1973, 1,603 articles listed authors from institutions in both the industry and the university sectors. This represented 13.1 percent of all articles carrying at least one author from industry, and 2.0 percent of articles with at least one university author.

[1] Based on the articles, notes, and reviews in over 2,100 influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information.

[2] U.S. institutions only.

SOURCE. Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 12 (tabulations prepared for the National Science Foundation, January, 1987)

See figure 5-10.

**Appendix table 5-14. United States cross-sector citations: 1973, 1977, 1981, and 1984**

| Sectors[1] | Year of cited papers | | | |
|---|---|---|---|---|
| | 1973 | 1977 | 1981 | 1984 |
| | — Relative citation index[2] — | | | |
| University articles citing: | | | | |
| Industry | 0.38 | 0.38 | 0.41 | 0.36 |
| Nonprofits | 1.03 | 0.93 | 0.93 | 0.60 |
| FFRDC's | 0.75 | 0.63 | 0.73 | 0.81 |
| Government | 0.82 | 0.84 | 0.81 | 0.53 |
| Industry articles citing: | | | | |
| University | 0.65 | 0.62 | 0.56 | 0.38 |
| Nonprofit | 0.46 | 0.43 | 0.48 | 0.28 |
| FFRDC's | 0.97 | 0.96 | 1.03 | 0.67 |
| Government | 0.75 | 0.77 | 0.67 | 0.54 |
| Nonprofit articles citing: | | | | |
| University | 0.95 | 0.93 | 0.83 | 0.62 |
| Industry | 0.25 | 0.26 | 0.24 | 0.45 |
| FFRDC's | 0.29 | 0.23 | 0.30 | 0.39 |
| Government | 1.01 | 1.06 | 0.96 | 0.69 |
| FFRDC articles citing: | | | | |
| University | 0.83 | 0.80 | 0.67 | 0.60 |
| Industry | 0.70 | 0.72 | 0.73 | 0.70 |
| Nonprofits | 0.40 | 0.31 | 0.28 | 0.26 |
| Government | 0.66 | 0.60 | 0.61 | 0.42 |
| Federal government articles citing: | | | | |
| University | 0.83 | 0.81 | 0.70 | 0.49 |
| Industry | 0.44 | 0.42 | 0.43 | 0.56 |
| Nonprofits | 1.12 | 1.01 | 0.97 | 0.47 |
| FFRDC's | 0.66 | 0.54 | 0.58 | 0.62 |

Note: Based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information.

[1] Articles are assigned to sectors based on the institutional addresses of the articles' authors. Articles with addresses from more than one sector are divided proportionately among the sectors.

[2] A citation ratio of 1.00 reflects no over- or under-citing of the sector's scientific and technical literature, whereas a higher ratio indicates a greater citation of that sector's articles for that year. For example, literature produced in the nonprofit sector in 1973 received 3 percent more citations from universities than would be expected based on the number of articles published.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 13 (tabulations prepared for the National Science Foundation, January 1987)

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## Appendix table 5-15. Institutional co-authorship between the industry and university sectors, by field: 1973-84

| Fields[1] | 1973 | 1977 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| | University-industry co-authored articles[2] as a percent of all industry articles | | | | | | |
| All fields | 13 | 15 | 19 | 22 | 24 | 23 | 25 |
| Clinical medicine | 21 | 23 | 30 | 30 | 34 | 33 | 35 |
| Biomedicine | 19 | 26 | 32 | 35 | 37 | 35 | 35 |
| Biology | 19 | 28 | 35 | 23 | 46 | 42 | 37 |
| Chemistry | 9 | 10 | 13 | 13 | 17 | 15 | 16 |
| Physics | 13 | 15 | 18 | 20 | 21 | 23 | 25 |
| Earth and space sciences | 28 | 27 | 31 | 34 | 35 | 33 | 36 |
| Engineering and technology | 9 | 10 | 13 | 16 | 17 | 16 | 17 |
| Mathematics | 28 | 39 | 39 | 43 | 35 | 43 | 42 |
| | University-industry co-authored papers[2] | | | | | | |
| All fields | 1,566 | 1,595 | 2,017 | 2,905 | 3.297 | 3,386 | 3584 |
| Clinical medicine | 329 | 331 | 467 | 636 | 768 | 779 | 916 |
| Biomedicine | 117 | 148 | 175 | 276 | 305 | 334 | 391 |
| Biology | 86 | 113 | 116 | 176 | 246 | 210 | 213 |
| Chemistry | 185 | 158 | 215 | 269 | 357 | 328 | 327 |
| Physics | 246 | 200 | 423 | 508 | 575 | 603 | 650 |
| Earth and space sciences | 102 | 95 | 119 | 207 | 241 | 222 | 251 |
| Engineering and technology | 463 | 418 | 459 | 746 | 732 | 811 | 757 |
| Mathematics | 38 | 42 | 43 | 89 | 73 | 100 | 79 |
| | Industry articles | | | | | | |
| All fields | 12,180 | 10,544 | 10,422 | 13,462 | 13,705 | 14,598 | 14220 |
| Clinical medicine | 1,600 | 1,413 | 1,533 | 2.086 | 2,257 | 2,394 | 2608 |
| Biomedicine | 618 | 567 | 548 | 782 | 824 | 966 | 1109 |
| Biology | 446 | 407 | 332 | 752 | 533 | 500 | 571 |
| Chemistry | 1,983 | 1,539 | 1,708 | 1,999 | 2,124 | 2,143 | 2007 |
| Physics | 1,911 | 1,932 | 2.302 | 2,559 | 2,713 | 2,623 | 2553 |
| Earth and space sciences | 358 | 348 | 381 | 606 | 691 | 664 | 698 |
| Engineering and technology | 5,130 | 4,231 | 3,507 | 4,770 | 4,356 | 5,075 | 4483 |
| Mathematics | 134 | 107 | 111 | 208 | 208 | 235 | 189 |

Note: Data for 1973-1980 are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. Data for 1981-1984 use over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes

[1] See appendix table 5-27 for a description of the subfields included in these fields

[2] Articles with authors from both the U.S. industrial sector and the U.S. university sector Foreign institutions are not divided into sectors

SOURCE. Computer Horizon, Inc., *Science Indicators Literature Data Base.* Series 12 (tabulations prepared for the National Science Foundation. January 1987)

See figure O-32 in Overview.

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Appendix table 5-16. Ways of relating to universities reported by business respondents, by size of company

| Ways of relating | All Respondents | Size of company (employees) | | | |
|---|---|---|---|---|---|
| | | 1-19 | 20-99 | 100-499 | 500+ |
| | Percent reporting | | | | |
| Employees attended conferences | 45 | 30 | 43 | 59 | 73 |
| Company recruited graduates | 41 | 19 | 41 | 57 | 81 |
| Company got technical services | 41 | 47 | 35 | 35 | 39 |
| Company provided financial aid for courses | 38 | 17 | 33 | 58 | 75 |
| Informal unpaid interaction | 28 | 25 | 23 | 28 | 45 |
| Company donated funds/equipment | 28 | 18 | 26 | 34 | 50 |
| Internships, co-op education | 23 | 10 | 17 | 31 | 53 |
| Company employed faculty consultants | 22 | 14 | 19 | 27 | 40 |
| Company contributed services to universities | 20 | 16 | 15 | 21 | 38 |
| Other professional interaction | 15 | 11 | 12 | 14 | 29 |
| Universities contributed services to company | 12 | 11 | 8 | 8 | 25 |
| Research contracts | 10 | 6 | 6 | 10 | 27 |
| Research grants/consortia | 7 | 4 | 3 | 8 | 19 |
| Universities reimbursed company for services | 5 | 5 | 3 | 2 | 7 |
| Universities held financial interest in company | 1 | 2 | [1] | 1 | 2 |
| Number of respondents | 1,246 | 458 | 274 | 174 | 192 |

[1] Less than 0.5 percent

SOURCE: Donald C. Pelz and Stuart L. Hart "Business Firm Study: Basic Data on Relations with Universities," Center for Research on Utilization of Knowledge, Institute for Social Research, University of Michigan, May 1, 1986

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## Appendix table 5-17. Ways of relating to universities reported by business respondents, by company stage of development

| Ways of relating | Start-up | Rapid growth | Steady growth | Stable | Declining |
|---|---|---|---|---|---|
| | Stage of development | | | | |
| | Percent responding | | | | |
| Employees attended conferences | 33 | 51 | 49 | 41 | 32 |
| Company recruited graduates | 25 | 58 | 45 | 34 | 27 |
| Company got technical services | 57 | 38 | 37 | 39 | 52 |
| Company provided financial aid for courses | 12 | 45 | 45 | 34 | 32 |
| Informal unpaid interaction | 28 | 32 | 28 | 27 | 19 |
| Company donated funds/equipment | 11 | 33 | 31 | 27 | 18 |
| Internships, co-op education | 14 | 30 | 26 | 20 | 15 |
| Company employed faculty consultants | 33 | 29 | 21 | 17 | 19 |
| Company contributed services to universities | 22 | 31 | 20 | 16 | 16 |
| Other professional interaction | 24 | 16 | 16 | 13 | 12 |
| Universities contributed services to company | 9 | 12 | 13 | 13 | 12 |
| Research contracts | 14 | 10 | 11 | 8 | 12 |
| Research grants/consortia | 7 | 6 | 7 | 8 | 6 |
| Universities reimbursed company for services | 4 | 7 | 5 | 4 | 3 |
| Universities held financial interest in company | 4 | 2 | 1 | 1 | 3 |
| Number of respondents | 81 | 202 | 488 | 368 | 68 |

SOURCE: Donald C. Pelz and Stuart L. Hart. Business Firm Study: Basic Data on Relations with Universities. Center for Research on Utilization of Knowledge, Institute for Social Research, University of Michigan, May 1, 1986

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## Appendix table 5-18. Faculty consultants to small business, by field and type of institution

| Field[1] | Total | Research universities | Other doctoral universities | Comprehensive colleges and universities | Baccalaureate institutions | Specialized S&T institutions |
|---|---|---|---|---|---|---|
| | Percent[2] | | | | | |
| Total | NA | 32.4 | 34.2 | 55.1 | 60.0 | 34.0 |
| Engineering | 29.8 | 23.5 | 25.0 | 44.4 | NA | 17.6 |
| Physical sciences | 43.6 | 41.2 | 34.1 | 50.0 | 62.5 | 43.5 |
| Environmental sciences | 52.1 | 22.2 | 30.8 | 100.0 | 100.0 | 0.0 |
| Computer sciences | 31.5 | 21.1 | 27.8 | 40.0 | 50.0 | 50.0 |
| Mathematics/statistics | 52.7 | 40.0 | 33.3 | 66.7 | 33.3 | 50.0 |
| Biological sciences | 52.2 | 40.8 | 51.1 | 56.0 | 64.3 | NA |

Note: Estimated from a national sample (N 29,395)

Note: NA - Not available.

[1] Field in which faculty member teaches

[2] Percent of faculty whose last consulting client was a small business

SOURCE: F. Darknell and D. Nasatir, Consulting as a Science Indicator, Final Report to the National Science Foundation under Grant SRS 8307778, May 1 1987 p. 33

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### Appendix table 5-19. Most active university patent classes: 1969-85

| Patent class | Total | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measuring and testing | 186 | 10 | 10 | 10 | 11 | 11 | 3 | 10 | 9 | 15 | 10 | 14 | 8 | 10 | 11 | 10 | 14 | 20 |
| Surgery | 306 | 9 | 9 | 5 | 10 | 20 | 8 | 24 | 13 | 17 | 14 | 14 | 21 | 17 | 29 | 26 | 36 | 34 |
| Chemistry, electrical & wave energy | 148 | 6 | 3 | 4 | 7 | 8 | 6 | 6 | 12 | 8 | 6 | 7 | 7 | 19 | 9 | 13 | 17 | 10 |
| Liquid purification or separation | 88 | 1 | 3 | 5 | 4 | 7 | 4 | 3 | 8 | 5 | 9 | 2 | 6 | 3 | 7 | 4 | 6 | 11 |
| Radiant energy | 135 | 1 | 4 | 5 | 6 | 7 | 8 | 6 | 15 | 17 | 9 | 4 | 7 | 8 | 9 | 7 | 13 | 9 |
| Chemistry, carbon compounds | 252 | 4 | 8 | 9 | 5 | 11 | 8 | 11 | 11 | 15 | 10 | 11 | 19 | 32 | 19 | 15 | 32 | 32 |
| Electricity, measuring & testing | 90 | 5 | 9 | 4 | 1 | 3 | 5 | 2 | 3 | 3 | 5 | 2 | 3 | 5 | 9 | 7 | 8 | 6 |
| Optics, systems & elements | 85 | 3 | 4 | 1 | 3 | 2 | 2 | 4 | 4 | 2 | 6 | 5 | 7 | 7 | 5 | 6 | 8 | 16 |
| Optics, measuring & testing | 77 | 1 | 5 | 9 | 1 | 2 | 3 | 1 | 5 | 3 | 2 | 6 | 8 | 8 | 2 | 9 | 3 | 9 |
| Electrical computers & data processing systems | 94 | 1 | 6 | 10 | 2 | 3 | 5 | 5 | 4 | 3 | 8 | 6 | 5 | 4 | 7 | 8 | 12 | 9 |
| X-ray or gamma ray systems | 58 | 1 | 1 | 2 | 2 | 6 | 2 | 2 | 8 | 6 | 8 | 2 | 2 | 0 | 8 | 1 | 3 | 4 |
| Chemistry, inorganic | 88 | 3 | 6 | 6 | 4 | 3 | 2 | 11 | 3 | 6 | 15 | 4 | 1 | 8 | 6 | 2 | 4 | 4 |
| Food or edible material | 88 | 2 | 0 | 3 | 4 | 4 | 7 | 7 | 4 | 9 | 4 | 4 | 6 | 5 | 7 | 9 | 5 | 8 |
| Drug, bio-affecting & body treating comps. (Patent class 424) | 248 | 4 | 6 | 9 | 5 | 4 | 8 | 13 | 14 | 16 | 15 | 9 | 10 | 19 | 30 | 27 | 40 | 19 |
| Stock material or misc. articles | 58 | 0 | 0 | 2 | 4 | 1 | 4 | 2 | 1 | 4 | 3 | 3 | 3 | 7 | 6 | 8 | 7 | 3 |
| Chemistry: mole. biol. & microbiology | 306 | 5 | 4 | 3 | 10 | 7 | 14 | 11 | 14 | 13 | 18 | 12 | 19 | 29 | 38 | 37 | 37 | 35 |
| Chemistry: analytical & immunological testing | 150 | 0 | 1 | 1 | 4 | 2 | 2 | 9 | 11 | 11 | 11 | 5 | 17 | 14 | 5 | 12 | 24 | 21 |
| Drug, bio-affecting & body treating compositions (Patent class 514) | 373 | 5 | 3 | 4 | 7 | 6 | 8 | 11 | 19 | 21 | 26 | 18 | 31 | 30 | 40 | 45 | 54 | 45 |
| Organic compounds, part of class 532-570 series, (Patent class 536) | 73 | 1 | 2 | 2 | 4 | 2 | 2 | 5 | 7 | 3 | 5 | 5 | 2 | 8 | 7 | 6 | 4 | 8 |
| Organic compounds, part of class 532-570 series, (Patent class 549) | 74 | 0 | 1 | 0 | 0 | 3 | 0 | 4 | 6 | 5 | 6 | 2 | 9 | 11 | 8 | 8 | 7 | 4 |
| Organic compounds, part of class 532-570 series, (Patent class 568) | 56 | 3 | 0 | 1 | 4 | 1 | 4 | 6 | 7 | 8 | 7 | 0 | 2 | 2 | 2 | 1 | 2 | 6 |
| Prosthesis, parts thereof or aids & accessories | 55 | 2 | 1 | 4 | 7 | 4 | 2 | 1 | 2 | 3 | 1 | 3 | 5 | 4 | 4 | 1 | 1 | 10 |

Note: Data are shown for the patent classes that accounted for one percent or more of total academic patenting activity.

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, special tabulations for National Science Foundation

## Appendix table 5-20. U.S. doctoral degrees awarded to foreign nationals, as a percent of all U.S. doctoral degrees, by field: 1960-86

| Field | 1960 | 1965 | 1970 | 1975 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All fields | 13.3 | 16.8 | 14.1 | 15.9 | 15.9 | 16.7 | 17.5 | 18.5 | 19.3 | 21.0 | 21.1 |
| Science and engineering | 18.2 | 22.0 | 18.2 | 21.7 | 20.8 | 21.4 | 22.0 | 23.4 | 24.5 | 26.6 | 26.7 |
| Physical sciences | 13.0 | 17.4 | 16.1 | 22.6 | 22.9 | 22.4 | 23.2 | 23.5 | 24.0 | 25.9 | 28.8 |
| Physics and astronomy | 14.2 | 19.8 | 17.3 | 27.2 | 24.4 | 25.2 | 27.3 | 29.4 | 28.0 | 31.3 | 34.1 |
| Chemistry | 12.5 | 15.8 | 15.1 | 18.8 | 22.6 | 21.8 | 22.7 | 23.7 | 27.5 | 22.7 | 25.5 |
| Earth sciences | 21.8 | 22.0 | 20.4 | 21.0 | 16.9 | 17.3 | 16.7 | 21.4 | 21.3 | 24.5 | 22.1 |
| Mathematical sciences | 23.6 | 16.5 | 15.7 | 23.7 | 26.7 | 30.1 | 32.3 | 35.0 | 36.3 | 37.3 | 40.8 |
| Mathematics | NA | NA | NA | NA | 27.0 | 31.5 | 32.4 | 36.4 | 38.4 | 40.7 | 42.2 |
| Computer sciences | NA | NA | NA | NA | 25.7 | 25.9 | 32.3 | 31.5 | 31.2 | 29.7 | 38.3 |
| Engineering | 30.1 | 29.0 | 26.2 | 41.1 | 46.4 | 49.2 | 50.1 | 53.5 | 53.0 | 54.8 | 50.7 |
| Life sciences | 21.8 | 13.6 | 18.7 | 19.2 | 16.5 | 16.1 | 15.4 | 16.4 | 16.9 | 19.0 | 18.2 |
| Biological sciences | 17.9 | 23.8 | 15.8 | 14.5 | 11.8 | 10.8 | 11.8 | 11.7 | 12.3 | 14.1 | 13.3 |
| Agriculture and forestry | 35.0 | 50.9 | 48.8 | 37.2 | 36.3 | 36.7 | 29.8 | 33.8 | 35.0 | 35.8 | [illegible] |
| Social sciences | 10.5 | 13.8 | 11.9 | 10.8 | 10.0 | 10.5 | 11.4 | 10.8 | 12.5 | 13.3 | [illegible] |
| Psychology | 5.6 | 4.5 | 5.2 | 5.7 | 3.9 | 3.8 | 3.5 | 4.3 | 4.2 | 4.6 | [illegible] |
| Other social sciences | 15.4 | 21.7 | 16.7 | 14.9 | 16.7 | 18.6 | 20.6 | 18.9 | 22.8 | 23.6 | [illegible] |
| Total nonscience | 6.9 | 8.5 | 7.7 | 8.6 | 9.8 | 10.6 | 11.5 | 11.8 | 12.3 | 13.1 | [illegible] |

SOURCE: National Science Foundation, *Science and Engineering Doctorates 1960-86* (forthcoming)

## Appendix table 5-21. U.S. doctoral recipients[1] studying abroad, by field: 1967-83

| Year | All S&E fields | Physics | Chemistry | Earth, env., & marine sciences | Engineering | Biosciences | Mathematics | Agricultural sciences | Social sciences | Psychology |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percent of doctoral recipients studying abroad | | | | | | | | | |
| 1967 ... | 2.13 | 3.49 | 4.33 | 1.73 | 1.11 | 3.70 | 1.39 | 0.71 | 0.20 | 0.73 |
| 1968 ... | 1.73 | 2.72 | 3.07 | 1.36 | 1.05 | 3.41 | 0.71 | 0.63 | 0.18 | 0.43 |
| 1969 ... | 1.86 | 3.97 | 3.19 | 2.87 | 0.91 | 3.39 | 0.32 | 0.97 | 0.33 | 0.54 |
| 1970 ... | 1.90 | 4.18 | 3.43 | 2.77 | 0.75 | 3.23 | 1.12 | 1.00 | 0.27 | 0.66 |
| 1971 ... | 2.39 | 5.59 | 5.72 | 3.16 | 1.56 | 3.22 | 0.74 | 0.90 | 0.16 | 0.64 |
| 1972 ... | 2.10 | 4.70 | 5.14 | 0.94 | 1.15 | 3.42 | 1.37 | 1.46 | 0.18 | 0.46 |
| 1973 ... | 1.44 | 3.42 | 2.27 | 1.81 | 0.63 | 2.70 | 1.45 | 1.13 | 0.29 | 0.30 |
| 1974 ... | 1.43 | 3.89 | 3.37 | 0.79 | 0.53 | 2.71 | 0.53 | 0.95 | 0.23 | 0.50 |
| 1975 ... | 1.54 | 2.80 | 3.03 | 0.94 | 1.02 | 3.10 | 1.11 | 0.79 | 0.36 | 0.46 |
| 1976 ... | 1.54 | 3.14 | 3.42 | 1.11 | 0.91 | 4.26 | 0.68 | 0.75 | 0.59 | 0.33 |
| 1977 ... | 1.33 | 3.16 | 2.23 | 2.75 | 0.82 | 3.62 | 0.58 | 0.78 | 0.43 | 0.25 |
| 1978 ... | 1.26 | 2.65 | 2.32 | 2.41 | 0.85 | 2.55 | 0.25 | 0.35 | 0.16 | 0.35 |
| 1979 ... | 1.61 | 2.99 | 2.10 | 1.77 | 1.15 | 3.37 | 1.21 | 1.05 | 0.48 | 0.31 |
| 1980 ... | 1.42 | 2.87 | 2.21 | 1.30 | 0.79 | 2.94 | 1.02 | 1.49 | 0.26 | 0.28 |
| 1981 ... | 1.73 | 4.91 | 2.41 | 2.25 | 0.98 | 3.51 | 0.79 | 1.27 | 0.37 | 0.25 |
| 1982 ... | 1.63 | 2.30 | 3.01 | 2.16 | 0.70 | 3.09 | 0.87 | 2.24 | 0.59 | 0.21 |
| 1983 ... | 1.46 | 3.43 | 2.74 | 1.95 | 1.08 | 2.31 | 0.66 | 1.55 | 0.52 | 0.26 |
| | Number of doctoral recipients studying abroad | | | | | | | | | |
| 1967 .. | 236 | 39 | 67 | 6 | 24 | 75 | 10 | 3 | 3 | 9 |
| 1968 .. | 214 | 34 | 49 | 5 | 25 | 83 | 6 | 3 | 3 | [illegible] |
| 1969 ... | 258 | 50 | 56 | 12 | 25 | 92 | 3 | 5 | 6 | 9 |
| 1970 ... | 296 | 60 | 70 | 12 | 22 | 96 | 12 | 6 | 6 | 12 |
| 1971 . | 397 | 84 | 115 | 16 | 46 | 105 | 8 | 6 | 4 | 13 |
| 1972 | 347 | 66 | 93 | 5 | 34 | 110 | 15 | 9 | 5 | 10 |
| 1973 | 234 | 45 | 37 | 10 | 17 | 88 | 15 | 7 | 8 | 7 |
| 1974 | 212 | 41 | 52 | 4 | 12 | 80 | 5 | 5 | 6 | 7 |
| 1975 | 235 | 29 | 46 | 5 | 21 | 96 | 11 | 5 | 10 | 12 |
| 1976 | 229 | 31 | 48 | 6 | 17 | 92 | 6 | 4 | 16 | 9 |
| 1977 | 191 | 29 | 30 | 16 | 14 | 75 | 5 | 4 | 11 | 7 |
| 1978 | 177 | 23 | 30 | 13 | 13 | 80 | 2 | 2 | 4 | 10 |
| 1979 | 228 | 26 | 28 | 10 | 18 | 110 | 10 | 6 | 11 | 9 |
| 1980 | 201 | 22 | 28 | 7 | 12 | 101 | 8 | 9 | 6 | 8 |
| 1981 | 245 | 38 | 32 | 11 | 14 | 120 | 6 | 8 | 8 | 8 |
| 1982 . | 225 | 17 | 41 | 12 | 10 | 106 | 6 | 15 | 12 | 6 |
| 1983 | 214 | 26 | 39 | 10 | 16 | 89 | 3 | 12 | 11 | 8 |
| | Number of all U.S. doctoral recipents | | | | | | | | | |
| 1967 . | 11.063 | 1.119 | 1.548 | 347 | 2,155 | 2,026 | 719 | 421 | 1,488 | 1,240 |
| 1968 .. | 12.397 | 1,249 | 1.594 | 367 | 2,378 | 2,436 | 841 | 479 | 1,647 | 1,406 |
| 1969 . | 13.846 | 1,258 | 1.753 | 418 | 2,736 | 2,712 | 937 | 516 | 1,845 | 1,671 |
| 1970 | 15.545 | 1,436 | 2.038 | 433 | 2,944 | 2,975 | 1,076 | 602 | 2,225 | 1,816 |
| 1971 | 16.589 | 1.503 | 2.011 | 506 | 2,948 | 3,264 | 1,074 | 663 | 2,578 | 2,042 |
| 1972 ... | 16530 | 1.403 | 1.808 | 531 | 2,952 | 3,216 | 1,095 | 618 | 2,738 | 2,169 |
| 1973 .. | 16,246 | 1.314 | 1.633 | 554 | 2,699 | 3,258 | 1,032 | 617 | 2,803 | 2,335 |
| 1974 | 14,840 | 1.054 | 1.542 | 504 | 2,267 | 2,957 | 947 | 526 | 2,652 | 2,391 |
| 1975 | 15.261 | 1.034 | 1.519 | 530 | 2,124 | 3,100 | 923 | 633 | 2,781 | 2,607 |
| 1976 | 14.851 | 987 | 1.405 | 540 | 1,947 | 3,160 | 803 | 536 | 2,705 | 2,768 |
| 1977 | 14.386 | 919 | 1.343 | 581 | 1,798 | 3,071 | 744 | 514 | 2,570 | 2.821 |
| 1978 | 14,056 | 868 | 1.293 | 540 | 1.586 | 3,134 | 666 | 573 | 2 448 | 2,858 |
| 1979 .. | 14,184 | 870 | 1.335 | 566 | 1.615 | 3,262 | 603 | 573 | 2,290 | 2,895 |
| 1980 ... | 14.114 | 766 | 1.269 | 538 | 1.554 | 3,234 | 582 | 627 | 2,292 | 2,796 |
| 1981 | 14.174 | 774 | 1,329 | 488 | 1.471 | 3.246 | 525 | 726 | 2,191 | 2,837 |
| 1982 .. | 13.855 | 741 | 1.369 | 557 | 1.465 | 3,399 | 499 | 660 | 2,043 | 2,965 |
| 1983 .. | 13.961 | 760 | 1.424 | 513 | 1.482 | 3,323 | 457 | 685 | 2,020 | 3,090 |

[1] Includes U S citizens and foreign citizens with permanent resident status

Incudes medical sciences

Includes computer science

SOURCE National Science Foundation *Science and Engineering Doctorates 1960-82* (NSF 83-328); National Research Council, *Summary Report 1983: Doctorate Recipients from United States Universities* National Academy Press Washington D C 1983 National Academy of Sciences, Doctorate Records File, unpublished data

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## Appendix table 5-22. U.S. academic exchange visas issued: 1978-86

| Country | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|
| Total | 67,579 | 72,131 | 77,557 | 84,106 | 85,714 | 91,164 | 97,646 | 89,448 | 102,854 |
| United Kingdom | 7,219 | 8,774 | 9,394 | 8,416 | 8,362 | 8,411 | 8,836 | 9,673 | 12,109 |
| France | 3,274 | 3,194 | 3,854 | 4,073 | 3,962 | 4,395 | 4,975 | 4,695 | 5,702 |
| West Germany | 3,572 | 3,996 | 4,420 | 4,649 | 5,208 | 5,823 | 7,415 | 7,013 | 7,914 |
| U.S.S.R | 176 | 275 | 234 | 180 | 183 | 160 | 98 | 104 | 328 |
| Poland | 905 | 1,008 | 1,184 | 1,374 | 1,122 | 863 | 990 | 718 | 737 |
| Other East Europe | 1,032 | 974 | 1,254 | 1,239 | 1,211 | 1,400 | 1,659 | 1,233 | 1,542 |
| Japan | 5,080 | 6,110 | 6,190 | 6,983 | 6,568 | 7,403 | 7,571 | 5,302 | 4,944 |
| Taiwan | 617 | 564 | 819 | 1,061 | 1,119 | 1,309 | 1,306 | 915 | 1,003 |
| Iran | 876 | 266 | 32 | 49 | 87 | 99 | 176 | 158 | 111 |
| Other countries | 44,828 | 46,970 | 50,176 | 56,082 | 57,892 | 61,301 | 64,620 | 59,637 | 68,464 |

SOURCE: Immigrant and Visa Control and Reporting Division, U.S. Department of State, unpublished data

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## Appendix table 5-23. Internationally co-authored articles, by field: 1973-84

| Field[1] | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Internationally co-authored articles as a percent of all institutionally co-authored articles[2] | | | | | | | | | | | |
| All fields | 12.7 | 13.3 | 14.0 | 14.8 | 15.1 | 15.4 | 16.1 | 16.3 | 17.3 | 17.2 | 17.8 | 18.5 |
| Clinical medicine | 6.6 | 6.9 | 6.8 | 7.8 | 7.5 | 7.7 | 8.1 | 8.1 | 8.8 | 9.1 | 9.7 | 9.9 |
| Biomedicine | 13.7 | 14.2 | 15.2 | 15.7 | 16.3 | 16.4 | 16.9 | 17.1 | 17.9 | 18.2 | 18.8 | 19.3 |
| Biology | 15.5 | 13.6 | 15.4 | 17.0 | 16.9 | 17.9 | 18.6 | 18.3 | 19.9 | 17.7 | 19.4 | 21.3 |
| Chemistry | 16.3 | 17.2 | 17.7 | 18.1 | 20.7 | 20.0 | 21.5 | 21.8 | 22.6 | 22.6 | 23.3 | 24.1 |
| Physics | 22.8 | 23.7 | 25.4 | 25.9 | 27.5 | 29.4 | 30.0 | 30.2 | 32.6 | 33.0 | 32.6 | 33.8 |
| Earth and space sciences | 23.1 | 22.5 | 24.6 | 27.7 | 27.5 | 28.7 | 28.7 | 30.7 | 30.2 | 30.5 | 32.1 | 34.1 |
| Engineering and technology | 13.2 | 14.0 | 15.5 | 14.0 | 16.2 | 17.2 | 18.2 | 18.2 | 19.7 | 19.9 | 20.7 | 20.9 |
| Mathematics | 34.3 | 39.5 | 39.8 | 38.6 | 37.9 | 38.8 | 40.0 | 42.5 | 42.0 | 43.9 | 44.7 | 47.8 |
| | Internationally co-authored articles | | | | | | | | | | | |
| All fields | 8,420 | 9,113 | 9,737 | 10,559 | 11,338 | 12,317 | 13,225 | 14,057 | 16,558 | 21,745 | 23,275 | 24,799 |
| Clinical medicine | 1,881 | 2,013 | 1,989 | 2,314 | 2,440 | 2,709 | 2,837 | 3,032 | 3,634 | 5,084 | 5,554 | 5,751 |
| Biomedicine | 1,454 | 1,581 | 1,775 | 1,862 | 2,032 | 2,156 | 2,395 | 2,533 | 2,828 | 3,765 | 3,965 | 4,181 |
| Biology | 723 | 655 | 779 | 853 | 915 | 1,007 | 1,116 | 1,051 | 1,371 | 1,804 | 2,034 | 2,308 |
| Chemistry | 1,088 | 1,241 | 1,286 | 1,384 | 1,546 | 1,600 | 1,763 | 1,932 | 2,253 | 2,802 | 2,857 | 3,073 |
| Physics | 1,570 | 1,757 | 1,933 | 2,142 | 2,320 | 2,548 | 2,758 | 2,960 | 3,470 | 4,217 | 4,334 | 4,646 |
| Earth and space sciences | 647 | 658 | 698 | 830 | 849 | 956 | 1,021 | 1,108 | 1,251 | 1,709 | 1,827 | 2,065 |
| Engineering and technology | 584 | 650 | 720 | 626 | 721 | 806 | 803 | 842 | 1,096 | 1,416 | 1,686 | 1,680 |
| Mathematics | 473 | 558 | 557 | 548 | 515 | 535 | 532 | 600 | 656 | 948 | 1,019 | 1,096 |
| | All institutionally co-authored articles | | | | | | | | | | | |
| All fields | 66,105 | 68,529 | 69,579 | 71,220 | 75,283 | 79,955 | 81,894 | 86,115 | 95,858 | 126,509 | 130,796 | 133,712 |
| Clinical medicine | 28,617 | 28,974 | 29,078 | 29,564 | 32,643 | 35,160 | 35,097 | 37,250 | 41,239 | 55,652 | 57,513 | 58,297 |
| Biomedicine | 10,648 | 11,117 | 11,683 | 11,845 | 12,436 | 13,116 | 14,144 | 14,807 | 15,839 | 20,642 | 21,114 | 21,713 |
| Biology | 4,660 | 4,829 | 5,073 | 5,024 | 5,405 | 5,620 | 5,985 | 5,744 | 6,875 | 10,188 | 10,483 | 10,818 |
| Chemistry | 6,694 | 7,224 | 7,264 | 7,632 | 7,485 | 7,996 | 8,185 | 8,856 | 9,986 | 12,393 | 12,266 | 12,759 |
| Physics | 6,897 | 7,410 | 7,601 | 8,271 | 8,433 | 8,661 | 9,179 | 9,792 | 10,651 | 12,772 | 13,289 | 13,747 |
| Earth and space sciences | 2,798 | 2,920 | 2,832 | 2,994 | 3,085 | 3,335 | 3,553 | 3,615 | 4,146 | 5,595 | 5,699 | 6,061 |
| Engineering and technology | 4,412 | 4,642 | 4,647 | 4,470 | 4,437 | 4,689 | 4,421 | 4,638 | 5,562 | 7,108 | 8,151 | 8,021 |
| Mathematics | 1,379 | 1,413 | 1,401 | 1,420 | 1,359 | 1,378 | 1,330 | 1,413 | 1,561 | 2,160 | 2,282 | 2,295 |

[1] See appendix table 5-27 for the subfields included in these fields.

[2] 1973-80 data are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. The 1981-84 data use over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 6 (special tabulations prepared for the National Science Foundation, November 1986)

See figure 5-12.

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## Appendix table 5-24. International co-authorship, by U.S. sector: 1973, 1980-84

| Sector | 1973 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|
| | Percent of articles involving cross-national collaboration | | | | | |
| University and colleges | 12.6 | 15.1 | 15.7 | 16.1 | 17.1 | 18.2 |
| Nonprofit institutions | 5.6 | 8.0 | 8.5 | 9.1 | 9.9 | 10.8 |
| FFRDC's | 11.9 | 20.4 | 20.4 | 23.3 | 23.1 | 24.7 |
| Federal government | 6.0 | 8.9 | 9.8 | 10.4 | 11.5 | 12.3 |
| Private industry for profit | 12.0 | 15.2 | 14.8 | 16.0 | 15.7 | 16.3 |
| | Number of articles involving cross-national collaboration | | | | | |
| University and colleges | 3,898 | 5,581 | 7,980 | 8,484 | 9,098 | 9,857 |
| Nonprofit institutions | 326 | 564 | 829 | 915 | 1,024 | 1,121 |
| FFRDC's | 235 | 464 | 615 | 714 | 757 | 829 |
| Federal government | 530 | 885 | 1,331 | 1,455 | 1,601 | 1,733 |
| Private industry for profit | 351 | 550 | 743 | 890 | 944 | 999 |
| | Total articles | | | | | |
| University and colleges | 30,998 | 36,923 | 50,941 | 52,825 | 53,184 | 54,271 |
| Nonprofit institutions | 5,803 | 7,080 | 9,736 | 10,017 | 10,371 | 10.380 |
| FFRDC's | 1,970 | 2,274 | 3,010 | 3,062 | 3,284 | 3,350 |
| Federal government | 8,898 | 9,984 | 13,593 | 13,952 | 13,953 | 14,134 |
| Private industry for profit | 2,930 | 3,621 | 5,009 | 5,577 | 6,009 | 6,129 |

Note: 1973 and 1980 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information 1981-84 data are based on over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes.

SOURCE: Computer Horizons, Inc, *Science Indicators Literature Data Base.* Series 12 (tabulations prepared for the National Science Foundation, January 1987)

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## Appendix table 5-25. Internationally co-authored articles and all institutionally co-authored articles, by country: 1973-84

| Country | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Internationally co-authored articles as a percent of all institutionally co-authored articles | | | | | | | | | | | |
| West Germany | 35.6 | 37.3 | 38.2 | 40.6 | 41.3 | 41.6 | 43.8 | 46.2 | 45.4 | 46.9 | 47.9 | 49.7 |
| United Kingdom | 35.3 | 37.0 | 37.7 | 39.6 | 40.7 | 40.2 | 40.4 | 41.8 | 41.8 | 41.6 | 41.3 | 42.9 |
| Canada | 37.0 | 45.6 | 37.3 | 38.5 | 38.4 | 39.4 | 39.9 | 40.0 | 42.7 | 42.7 | 40.2 | 42.0 |
| France | 26.7 | 26.9 | 29.8 | 31.4 | 32.5 | 33.5 | 33.9 | 34.0 | 34.9 | 37.3 | 38.6 | 39.6 |
| U.S.S.R | 9.6 | 10.9 | 13.3 | 14.2 | 17.3 | 16.3 | 20.1 | 19.9 | 18.3 | 18.5 | 18.5 | 18.1 |
| United States | 14.0 | 14.3 | 15.0 | 15.9 | 15.9 | 15.7 | 16.6 | 16.9 | 17.6 | 18.2 | 19.2 | 20.3 |
| Japan | 16.4 | 16.4 | 16.1 | 15.2 | 15.9 | 15.5 | 16.3 | 16.4 | 17.3 | 18.2 | 18.3 | 19.3 |
| | Internationally co-authored articles | | | | | | | | | | | |
| West Germany | 1,283 | 1,527 | 1,568 | 1,741 | 1,923 | 2,176 | 2,244 | 2,459 | 3557 | 3,767 | 4,058 | 4,292 |
| United Kingdom | 2,029 | 2,219 | 2,364 | 2,574 | 2,633 | 2,784 | 2,889 | 3,159 | 4492 | 4,626 | 4,857 | 5,150 |
| Canada | 1,302 | 1,369 | 1,422 | 1,532 | 1,599 | 1,715 | 1,812 | 1,819 | 2718 | 2,861 | 2,862 | 3,183 |
| France | 1,131 | 1,209 | 1,460 | 1,591 | 1,769 | 1,837 | 2,003 | 2,153 | 3062 | 3,342 | 3,546 | 3,761 |
| U.S.S.R | 288 | 318 | 380 | 432 | 523 | 528 | 604 | 637 | 836 | 900 | 929 | 869 |
| United States | 07 | 5,037 | 5,254 | 5,675 | 5,972 | 6,248 | 6,755 | 7,192 | 10268 | 11,013 | 11,830 | 12,743 |
| Japan | 472 | 495 | 543 | 555 | 635 | 678 | 767 | 872 | 1334 | 1,516 | 1,645 | 1,878 |
| | All institutionally co-authored articles | | | | | | | | | | | |
| West Germany | 3,605 | 4,093 | 4,108 | 4,287 | 4,654 | 5.228 | 5,128 | 5,324 | 7842 | 8,037 | 8,469 | 8,628 |
| United Kingdom | 5,749 | 6,002 | 6,268 | 6.501 | 6,473 | 6,925 | 7,159 | 7,553 | 10747 | 11,131 | 11,762 | 12,014 |
| Canada | 3,521 | 3,004 | 3,809 | 3,976 | 4,166 | 4,358 | 4,543 | 4,542 | 6368 | 6.697 | 7,113 | 7,578 |
| France | 4,233 | 4,492 | 4,901 | 5,065 | 5,445 | 5,491 | 5,902 | 6,341 | 8779 | 8,967 | 9,175 | 9,499 |
| U.S.S.R | 3,011 | 2,926 | 2,860 | 3,033 | 3,031 | 3,233 | 3,005 | 3,199 | 4578 | 4,876 | 5,015 | 4,796 |
| United States | 34,364 | 35,338 | 35,100 | 35,799 | 37,618 | 39,768 | 40,784 | 42,508 | 58472 | 60,649 | 61,688 | 62,861 |
| Japan | 2,881 | 3,018 | 3,363 | 3,657 | 3,984 | 4,386 | 4,696 | 5,308 | 7699 | 8,336 | 8,988 | 9,722 |

Note: 1973-80 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information 1981-84 data are based on over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes.

SOURCE: Computer Horizons, Inc, *Science Indicators Literature Data Base.* Series 6 (tabulations prepared for the National Science Foundation, January 1987)

See figure 5-13.

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## Appendix table 5-26. U.S. and world scientific and technical articles, by field: 1973-84

| Field[1] | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | U.S. articles as a percent of all articles | | | | | | | | | | | |
| All fields .......... | 38 | 38 | 37 | 37 | 37 | 38 | 37 | 37 | 35 | 35 | 35 | 35 |
| Clinical medicine . | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 41 | 41 | 40 | 41 |
| Biomedicine ..... | 39 | 38 | 39 | 39 | 39 | 39 | 40 | 40 | 39 | 40 | 39 | 39 |
| Biology ......... | 46 | 46 | 45 | 44 | 42 | 42 | 43 | 42 | 37 | 38 | 38 | 37 |
| Chemistry ....... | 23 | 22 | 22 | 22 | 22 | 21 | 21 | 21 | 20 | 21 | 20 | 21 |
| Physics ......... | 33 | 33 | 32 | 31 | 30 | 31 | 30 | 30 | 28 | 27 | 28 | 27 |
| Earth and space sciences ...... | 47 | 47 | 44 | 46 | 45 | 45 | 45 | 42 | 42 | 42 | 42 | 41 |
| Engineering and technology .... | 42 | 42 | 41 | 41 | 40 | 39 | 41 | 39 | 38 | 38 | 41 | 40 |
| Mathematics ..... | 48 | 46 | 44 | 43 | 41 | 40 | 40 | 40 | 36 | 37 | 38 | 37 |
| | Number of U.S. articles[2] | | | | | | | | | | | |
| All fields .......... | 103,777 | 100,066 | 97,278 | 99,970 | 97,854 | 99,207 | 99,377 | 98,394 | 134,940 | 135,953 | 132,415 | 131,111 |
| Clinical medicine . | 32,638 | 31,691 | 31,334 | 32,920 | 33,516 | 34,966 | 33,975 | 34,612 | 49,082 | 49,458 | 48,055 | 48,735 |
| Biomedicine ..... | 16,115 | 15,607 | 15,901 | 16,271 | 16.197 | 16,611 | 17,649 | 17,582 | 22,029 | 22,892 | 22,496 | 22,196 |
| Biology ......... | 11.150 | 10,700 | 10,400 | 10.573 | 9,904 | 9,663 | 10,553 | 9,594 | 15,070 | 15,199 | 14,216 | 14,166 |
| Chemistry ....... | 10,474 | 9,867 | 9,222 | 9,337 | 8,852 | 9,266 | 9,182 | 9,250 | 10,946 | 11,820 | 11,010 | 11,137 |
| Physics ......... | 11,721 | 11,945 | 11,363 | 11,502 | 10.995 | 11,015 | 10,995 | 11,415 | 13,111 | 13,315 | 13,021 | 12,691 |
| Earth and space sciences ...... | 5,591 | 5,371 | 4,975 | 5,537 | 5,197 | 5,043 | 5,167 | 4,832 | 7,421 | 7,220 | 6,862 | 6,748 |
| Engineering and technology .... | 11,955 | 11,088 | 10,431 | 10,346 | 10,081 | 9,694 | 9,018 | 8,461 | 13,282 | 12,284 | 13,105 | 11,976 |
| Mathematics ... . | 4,134 | 3,797 | 3,652 | 3,484 | 3,112 | 2,949 | 2,838 | 2,648 | 4,000 | 3,765 | 3,648 | 3,462 |
| | Number of all articles | | | | | | | | | | | |
| All fields .......... | 271,513 | 265,130 | 260,908 | 267,354 | 263,700 | 270,128 | 267,953 | 269,556 | 382,327 | 383,697 | 373,550 | 369,930 |
| Clinical medicine . | 76,209 | 74,509 | 73,485 | 76,699 | 77,597 | 81,209 | 78,827 | 80,533 | 119,477 | 120,926 | 119,325 | 119,094 |
| Biomedicine ..... | 41,155 | 40,632 | 41,244 | 41,891 | 41,388 | 42,968 | 43,631 | 44,267 | 55,787 | 57,585 | 57,289 | 56,223 |
| Biology ......... | 24,047 | 23,414 | 23,260 | 23,905 | 23,757 | 23,176 | 24,734 | 22,838 | 40,328 | 39,875 | 37,788 | 38,093 |
| Chemistry ....... | 45,004 | 44,529 | 42,502 | 42,773 | 40,734 | 43,550 | 43,273 | 44,448 | 55,789 | 56,630 | 54,186 | 54,117 |
| Pnysics ......... | 35,854 | 35,708 | 35,104 | 36,902 | 36,057 | 35,515 | 36,700 | 37,944 | 46,913 | 48,677 | 46,902 | 46,450 |
| Earth and space sciences ...... | 11,977 | 11,479 | 11,356 | 12,011 | 11,531 | 11,224 | 11,596 | 11,395 | 17,656 | 17,241 | 16,508 | 16,334 |
| Engineering and technology .... | 28,617 | 26,600 | 25,664 | 25,146 | 25,003 | 24,588 | 22,182 | 21,459 | 35,248 | 32,598 | 32,073 | 30,310 |
| Mathematics ..... | 8,639 | 8,259 | 8,293 | 8,127 | 7,573 | 7,298 | 7,011 | 6,673 | 11,128 | 10,165 | 9,478 | 9,309 |

Note: 1973-80 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information. 1981-84 data are based on over 3,500 journals on the 1981 Science Citation Index Corporate Tapes

Note: Detail may not add to totals because of rounding.

[1] See appendix table 5-27 for the subfields included in these fields

[2] When an article is written by researchers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States it is split on the basis of these countries regardless of the number of organizations represented by the authors

SOURCE: Computer Horizons, Inc. *Science Indicators Literature Data Base*. Series 1 (tabulations prepared for the National Science Foundation, January 1987)

See table O-3 in Overview

## Appendix table 5-27. Publications in the fields and subfields of international scientific literature: 1984

| Field and subfield | World | United States |
|---|---|---|
| Clinical medicine | 119,094 | 48,735 |
| General & internal medicine | 17,553 | 5,802 |
| Allergy | 702 | 291 |
| Anesthesiology | 1,325 | 450 |
| Cancer | 5,920 | 2,727 |
| Cardiovascular system | 4,994 | 2,357 |
| Dentistry | 2,435 | 1,140 |
| Dermatology & venereal diseases | 2,853 | 1,052 |
| Endocrinology | 4,495 | 1,688 |
| Fertility | 1,179 | 535 |
| Gastroenterology | 1,910 | 605 |
| Geriatrics | 767 | 491 |
| Hematology | 2,228 | 790 |
| Immunology | 7,918 | 3,582 |
| Obstetrics & gynecology | 2,319 | 1,010 |
| Neurology & neurosurgery | 10,472 | 4,522 |
| Ophthalmology | 2,363 | 1,116 |
| Orthopedics | 1,149 | 504 |
| Arthritis & rheumatism | 904 | 275 |
| Otorhinolaryngology | 1,392 | 654 |
| Pathology | 2,928 | 989 |
| Pediatrics | 2,824 | 1,227 |
| Pharmacology | 10,901 | 3,674 |
| Pharmacy | 4,051 | 1,110 |
| Psychiatry | 2,289 | 1,384 |
| Radiology & nuclear medicine | 5,109 | 2,683 |
| Respiratory system | 1,556 | 657 |
| Surgery | 5,025 | 2,667 |
| Tropical medicine | 646 | 154 |
| Urology | 1,643 | 811 |
| Nephrology | 522 | 197 |
| Veterinary medicine | 5,477 | 1,790 |
| Addictive diseases | 443 | 270 |
| Hygiene & public health | 2,408 | 1,295 |
| Miscellaneous clinical medicine | 394 | 236 |
| Biomedicine | 56,223 | 22,196 |
| Physiology | 3,910 | 1,638 |
| Anatomy & morphology | 822 | 251 |
| Embryology | 1,003 | 419 |
| Genetics & heredity | 4,573 | 1,625 |
| Nutrition & dietetics | 1,665 | 832 |
| Biochemistry & molecular biology | 19,043 | 7,535 |
| Biophysics | 975 | 327 |
| Cell biology, cytology & histology | 5,115 | 1,992 |
| Microbiology | 4,640 | 1,660 |
| Virology | 1,863 | 788 |
| Parasitology | 1,236 | 500 |
| Biomedical engineering | 1,532 | 630 |
| Microscopy | 388 | 133 |
| Miscellaneous biomedicine | 1,521 | 715 |
| General biomedicine | 7,938 | 3,150 |
| Biology | 38,093 | 3,990 |
| General biology | 1,593 | 14,166 |
| General zoology | 2,121 | 463 |
| Entomology | 3,018 | 402 |
| Miscellaneous zoology | 3,027 | 1,610 |
| Marine biology & hydrobiology | 3,418 | 1,107 |
| Botany | 9,491 | 3,347 |
| Ecology | 2,771 | 1,219 |
| Agriculture & food science | 8,526 | 3,194 |
| Dairy animal science | 3,315 | 1,361 |
| Miscellaneous biology | 2,435 | 1,140 |
| Chemistry | 54,117 | 11,137 |
| Analytical chemistry | 5,884 | 1,528 |
| Organic chemistry | 8,155 | 2,004 |
| Inorganic & nuclear chemistry | 4,243 | 745 |
| Applied chemistry | 2,367 | 386 |
| General chemistry | 16,436 | 2,695 |
| Polymers | 4,118 | 893 |
| Physical chemistry | 12,913 | 2,885 |
| Physics | 46,450 | 12,691 |
| Chemical physics | 5,328 | 1,923 |
| Solid state physics | 8,298 | 1,951 |
| Fluids & plasmas | 1,031 | 538 |
| Applied physics | 10,302 | 2,761 |
| Acoustics | 1,130 | 482 |
| Optics | 1,940 | 778 |
| General physics | 13,448 | 2,636 |
| Nuclear & particle physics | 3,814 | 1,299 |
| Miscellaneous physics | 1,159 | 324 |
| Earth & space science | 16,334 | 6,748 |
| Astronomy & astrophysics | 3,760 | 1,605 |
| Meteorology & atmospheric science | 1,545 | 923 |
| Geology | 2,907 | 1,135 |
| Earth & planetary science | 6,432 | 2,402 |
| Geography | 2,408 | 1,295 |
| Oceanography & limnology | 1,635 | 674 |
| Engineering and technology | 30,310 | 11,976 |
| Chemical engineering | 3,003 | 1,312 |
| Mechanical engineering | 3,036 | 1,224 |
| Civil engineering | 1,926 | 1,147 |
| Electrical engineering & electronics | 7,419 | 2,970 |
| Miscellaneous engineering & technology | 632 | 200 |
| Industrial engineering | 19,043 | 7,535 |
| General engineering | 1,046 | 195 |
| Metals & metallurgy | 3,855 | 817 |
| Materials science | 3,720 | 1,412 |
| Nuclear technology | 2,004 | 829 |
| Aerospace technology | 1,236 | 500 |
| Computers | 1,860 | 914 |
| Library & information science | 388 | 133 |
| Operations research & management science | 7,938 | 3,150 |
| Mathematics | 9,309 | 3,462 |
| Probability and statistics | 1,593 | 14,166 |
| Applied mathematics | 2,121 | 463 |
| General mathematics | 4,706 | 1,385 |
| Miscellaneous mathematics | 3,027 | 1,610 |
| All fields | 369,930 | 131,111 |

Note: Based on the articles, notes and reviews in over 3,500 of the influential journals carried on the 1981 *Science Citation Index* Corporate Tapes.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 1 (tabulations prepared for the National Science Foundation, January 1987)

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## Appendix table 5-28. Total references in U.S. articles and references in U.S. articles to articles from other countries,[1] by field: 1974-84

| Field[2] | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Publication year of citing articles | | | | | | | | | | |
| | Percentage of references in U.S. articles to articles from other countries | | | | | | | | | | |
| All fields | 23.0 | 24.7 | 26.6 | 26.9 | 38.0 | 27.8 | 28.4 | 28.7 | 28.9 | 28.9 | 29.3 |
| Clinical medicine | 20.6 | 23.1 | 24.1 | 24.5 | 25.3 | 25.4 | 25.6 | 25.9 | 26.0 | 26.3 | 26.3 |
| Biomedical research | 22.9 | 25.7 | 27.2 | 27.7 | 29.6 | 28.5 | 29.0 | 29.3 | 29.4 | 29.6 | 29.7 |
| Biology | 19.8 | 22.1 | 23.0 | 24.3 | 24.7 | 26.4 | 27.3 | 27.6 | 27.[illegible] | 27.2 | 27.9 |
| Chemistry | 32.1 | 32.0 | 37.5 | 36.4 | 37.6 | 36.8 | 37.9 | 36.8 | 38.[illegible] | 38.3 | 38.0 |
| Physics | 24.7 | 25.9 | 27.2 | 28.3 | 29.5 | 30.6 | 31.3 | 32.5 | 33.4 | 33.3 | 34.9 |
| Earth and space sciences | 17.7 | 20.5 | 21.3 | 22.0 | 23.1 | 22.9 | 24.3 | 24.4 | 24.8 | 23.3 | 25.8 |
| Engineering and technology | 20.3 | 20.9 | 23.3 | 23.2 | 24.0 | 24.8 | 25.0 | 26.0 | 26.0 | 26.1 | 27.2 |
| Mathematics | 16.2 | 18.4 | 21.3 | 24.4 | 25.6 | 25.9 | 27.8 | 28.4 | 28.0 | 29.1 | 28.5 |
| | References in U.S. articles to articles from other countries | | | | | | | | | | |
| All fields | 38,450 | 79,569 | 120,676 | 154,821 | 182,805 | 219,434 | 243,580 | 283,006 | 310,817 | 336207 | 321681 |
| Clinical medicine | 9,801 | 23,552 | 36,771 | 49,403 | 61,336 | 69,332 | 77,558 | 90,439 | 97,747 | 105711 | 102682 |
| Biomedical research | 10,360 | 22,010 | 33,549 | 42,677 | 45,010 | 63,614 | 71,024 | 81,833 | 89,130 | 95977 | 91719 |
| Biology | 1,591 | 3,826 | 5,448 | 7,789 | 9,374 | 11,886 | 13,793 | 16,935 | 18,453 | 20283 | 19561 |
| Chemistry | 6,487 | 10,558 | 18,828 | 21,469 | 26,055 | 27,064 | 31,314 | 34,126 | 38,677 | 38513 | 36583 |
| Physics | 6,665 | 11,863 | 16,286 | 21,127 | 24,824 | 27,461 | 29,831 | 36,039 | 40,197 | 44158 | 41987 |
| Earth and space sciences | 1,961 | 4,920 | 5,479 | 7,154 | 9,528 | 12,336 | 11,746 | 13,606 | 15,637 | 19800 | 18566 |
| Engineering and technology | 1,341 | 2,287 | 3,351 | 3,858 | 4,879 | 5,892 | 6,256 | 7,702 | 8,583 | 8994 | 8220 |
| Mathematics | 244 | 554 | 968 | 1,344 | 1,799 | 1,847 | 2,057 | 2,325 | 2,395 | 2771 | 2362 |
| | Total references in U.S. articles | | | | | | | | | | |
| All fields | 167,397 | 321,661 | 454,107 | 576,508 | 654,107 | 788,728 | 857,782 | 987,027 | 1,074,351 | 1162450 | 1096233 |
| Clinical medicine | 47,693 | 102,033 | 152,429 | 201,772 | 242,170 | 273,094 | 303,335 | 349,179 | 375,595 | 401784 | 390221 |
| Biomedical research | 45,282 | 85,622 | 123,445 | 154,313 | 151,938 | 222,833 | 245,325 | 279,411 | 303,674 | 323917 | 308776 |
| Biology | 8,017 | 17,286 | 23,639 | 32,059 | 37,999 | 44,971 | 50,456 | 61,263 | 68,027 | 74523 | 70135 |
| Chemistry | 20,221 | 32,962 | 50,195 | 58,986 | 69,237 | 73,543 | 82,646 | 92,729 | 101,871 | 100596 | 96242 |
| Physics | 26,981 | 45,808 | 59,807 | 74,754 | 84,250 | 89,637 | 95,264 | 110,806 | 120,421 | 132547 | 120398 |
| Earth and space sciences | 11,086 | 23,989 | 25,675 | 32,474 | 41,171 | 53,760 | 48,360 | 55,851 | 63,177 | 85056 | 71933 |
| Engineering and technology | 6,609 | 10,948 | 14,376 | 16,632 | 20,315 | 23,750 | 24,999 | 29,601 | 33,037 | 34517 | 30234 |
| Mathematics | 1,508 | 3,012 | 4,542 | 5,517 | 7,027 | 7,139 | 7,398 | 8,189 | 8,550 | 9510 | 8295 |

[1] The number of references found in articles written by scientists and engineers at U.S. institutions, and the number of references in articles written by U S authors which were to articles written by S/E's at foreign institutions. References were sought in the articles published in over 2,100 influential journals carried on the Corporate Tapes of the 1973 *Science Citation Index* of the Institute of Scientific Information.

[2] See appendix table 5-27 for subfields included in the fields.

SOURCE: Computer Horizons, Inc.. *Science Indicators Literature Data Base*, Series 2 (Tabulations prepared for the National Science Foundation, January 1987)

See figure O-21 in Overview.

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3?? 

## Appendix table 5-29. Relative citation ratios[1] for U.S. articles by field: 1973-82

| Field | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Publication year of cited articles | | | | | | | | | |
| World citations to U.S.: | | | | | | | | | | |
| All fields | 1.39 | 1.41 | 1.41 | 1.40 | 1.42 | 1.41 | 1.41 | 1.43 | 1.38 | 1.37 |
| Clinical medicine | 1.35 | 1.36 | 1.36 | 1.34 | 1.34 | 1.35 | 1.34 | 1.34 | 1.33 | 1.32 |
| Biomedicine | 1.42 | 1.43 | 1.41 | 1.42 | 1.43 | 1.39 | 1.38 | 1.42 | 1.36 | 1.34 |
| Biology | 1.08 | 1.12 | 1.11 | 1.11 | 1.16 | 1.15 | 1.16 | 1.17 | 1.15 | 1.12 |
| Chemistry | 1.64 | 1.64 | 1.68 | 1.65 | 1.69 | 1.71 | 1.72 | 1.76 | 1.67 | 1.63 |
| Physics | 1.54 | 1.53 | 1.53 | 1.55 | 1.56 | 1.50 | 1.56 | 1.54 | 1.49 | 1.50 |
| Earth and space sciences | 1.37 | 1.38 | 1.44 | 1.36 | 1.39 | 1.39 | 1.45 | 1.46 | 1.43 | 1.49 |
| Engineering and technology | 1.28 | 1.28 | 1.27 | 1.23 | 1.28 | 1.31 | 1.29 | 1.27 | 1.23 | 1.18 |
| Mathematics | 1.24 | 1.23 | 1.22 | 1.20 | 1.27 | 1.32 | 1.24 | 1.25 | 1.25 | 1.23 |
| Non-U.S. citations to U.S.: | | | | | | | | | | |
| All fields | 1.04 | 1.03 | 1.02 | 1.01 | 1.00 | 0.98 | 0.97 | 0.96 | 0.88 | 0.83 |
| Clinical medicine | 1.03 | 1.02 | 1.02 | 1.00 | 0.99 | 0.98 | 0.95 | 0.93 | 0.89 | 0.83 |
| Biomedicine | 1.10 | 1.08 | 1.07 | 1.07 | 1.06 | 1.00 | 0.99 | 1.00 | 0.92 | 0.87 |
| Biology | 0.71 | 0.71 | 0.69 | 0.68 | 0.69 | 0.66 | 0.66 | 0.65 | 0.61 | 0.53 |
| Chemistry | 1.21 | 1.16 | 1.18 | 1.13 | 1.14 | 1.14 | 1.09 | 1.11 | 0.98 | 0.92 |
| Physics | 1.21 | 1.18 | 1.17 | 1.17 | 1.16 | 1.08 | 1.12 | 1.07 | 1.00 | 0.97 |
| Earth and space sciences | 1.06 | 1.06 | 1.10 | 1.03 | 1.04 | 1.05 | 1.07 | 1.05 | 0.97 | 0.99 |
| Engineering and technology | 0.92 | 0.86 | 0.84 | 0.80 | 0.80 | 0.83 | 0.79 | 0.73 | 0.67 | 0.55 |
| Mathematics | 0.91 | 0.90 | 0.86 | 0.81 | 0.85 | 0.88 | 0.80 | 0.77 | 0.70 | 0.68 |
| U.S. citations to U.S.: | | | | | | | | | | |
| All fields | 1.85 | 1.88 | 1.90 | 1.90 | 1.93 | 1.95 | 1.96 | 2.01 | 1.99 | 2.02 |
| Clinical medicine | 1.70 | 1.72 | 1.72 | 1.72 | 1.73 | 1.75 | 1.74 | 1.77 | 1.80 | 1.84 |
| Biomedicine | 1.78 | 1.82 | 1.80 | 1.82 | 1.83 | 1.82 | 1.79 | 1.85 | 1.81 | 1.81 |
| Biology | 1.55 | 1.62 | 1.63 | 1.64 | 1.72 | 1.75 | 1.73 | 1.78 | 1.80 | 1.79 |
| Chemistry | 2.62 | 2.75 | 2.80 | 2.82 | 2.91 | 2.97 | 3.01 | 3.10 | 3.08 | 3.11 |
| Physics | 2.08 | 2.09 | 2.14 | 2.20 | 2.23 | 2.19 | 2.28 | 2.28 | 2.27 | 2.33 |
| Earth and space sciences | 1.63 | 1.64 | 1.74 | 1.64 | 1.68 | 1.68 | 1.76 | 1.79 | 1.77 | 1.84 |
| Engineering and technology | 1.77 | 1.79 | 1.83 | 1.77 | 1.84 | 1.90 | 1.87 | 1.92 | 1.87 | 1.88 |
| Mathematics | 1.58 | 1.60 | 1.63 | 1.68 | 1.77 | 1.84 | 1.79 | 1.86 | 1.94 | 1.94 |

Note: Based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information For the size of this data base, and the subfields included in the fields, see appendix table 5-27.

[1] The share of citations made to U.S. publications in a field during a particular year, divided by the U S share of publications in that year and field. A citation ratio of 1.00 reflects no over- or under-citing of the U.S. scientific and technical literature, whereas a higher ratio indicates a greater influence, impact or utility than would have been expected from the number of U.S articles for that year For example, the U S chemistry literature for 1973 received 64 percent more citations than expected from the world's chemistry articles.

SOURCE: Computer Horizons, Inc , *Science Indicators Literature Data Base*, Series 5 (tabulations prepared for the National Science Foundation, January 1987)

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## Appendix table 5-30. International collaboration in Deep Sea Drilling Project research areas

| | Collaboration Rate[1] |
|---|---|
| All earth and space sciences, 1982[2] | 30 |
| 1983 selected research areas:[3] | |
| Deep sea drilling project results: Hydrothermal Mounds of the Galapagos Rift and Other Spreading Centers | 41 |
| Basin Evolution and Tectonic History of the Mesozoic Atlantic and Tethys from Deep-Sea Drilling Poject data | 64 |
| Eocene, Oligocene, and Miocene Stratigraphy and Paleoceanography Evidenced by Foraminiferal Faunas Recovered by the Deep-Sea Drilling Project | 58 |
| Seismic Studies of Crustal Structure and Deep-Sea Drilling Project Data from the Atlantic Ocean and Costa Rica Rift | 40 |
| Cenozoic Stratigraphy of the Atlantic, Pacific, and Indian Oceans Based on the Calcareous Nannofossils Recovered by the Deep-Sea Drilling Project | 58 |
| 1985 selected research areas:[3] | |
| Deep-Sea Drilling Evidence of Evolution, Paleoenvironmental and Catastrophic Extinction | 39 |
| Oxygen and Carbon Isotopes in Sediments from Deep-Sea Drilling Sediments | 40 |
| Late Cenozoic Magnetostratigraphy and Biostratigraphy from Deep-Sea Drilling Sediments | 55 |
| Quaternary Biostratigraphy and Climate History from Deep-Sea Drilling Sediments | 35 |
| Cenozoic Climates, Stratigraphy and Paleoceanography from Deep-Sea Drilling Project Sites in the Atlantic and Pacific Oceans | 33 |

[1] The percentage of multi-author U.S. articles which have at least one author with a non- U.S address

[2] Based on over 3500 influential journals carried on the 1981 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

[3] Identified through cocitation clustering. Analysis provided by the Institute for Scientific Information

SOURCE: Institute for Scientific Information, special tabulations prepared for the National Science Foundation, Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 6 (tabulations prepared for the National Science Foundation, January 1987)

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## Appendix table 5-31. Doctoral scientists and engineers leaving research for new activities: 1973/75 to 1983/85

| Year | Moved from research to: | | |
|---|---|---|---|
| | Development | R&D management | Teaching |
| | Percent | | |
| Scientists: | | | |
| 1973-75 | 2.2 | 6.8 | 12.2 |
| 1975-77 | 2.4 | 7.8 | 9.7 |
| 1977-79 | 2.4 | 12.5 | 11.0 |
| 1979-81 | 1.6 | 4.3 | 10.7 |
| 1981-83 | 3.1 | 5.8 | 8.7 |
| 1983-85 | 2.9 | 5.5 | 7.6 |
| Engineers: | | | |
| 1973-75 | 13.5 | 13.4 | 7.5 |
| 1975-77 | 13.7 | 13.3 | 7.4 |
| 1977-79 | 9.4 | 25.4 | 10.3 |
| 1979-81 | 11.7 | 6.2 | 9.5 |
| 1981-83 | 11.4 | 14.9 | 9.6 |
| 1983-85 | 11.2 | 8.0 | 5.5 |

Note: Data includes those who listed basic or applied research as their primary work activity for the earlier years

SOURCE: National Academy of Sciences, Doctorate Record File, special tabulation for the National Science Foundation.

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3 : 2

## Appendix table 6-1. Industry performance and funding of research and development, for selected countries: 1970-87

| Year | France | West Germany | Japan | United Kingdom | United States |
|---|---|---|---|---|---|
| | | | R&D performed by industry — Millions national currency | | |
| 1970 | 8.322 | 8.900 | 823.265 | NA | 18.067 |
| 1971 | 9.336 | 10.521 | 895.020 | NA | 18.320 |
| 1972 | 10.570 | 11.170 | 1.044.928 | 831 | 19.552 |
| 1973 | 11.524 | 11.761 | 1.301.927 | NA | 21.249 |
| 1974 | 13.531 | 12.733 | 1.589.053 | NA | 22.887 |
| 1975 | 15.617 | 14,469 | 1.684.847 | 1 340 | 24.187 |
| 1976 | 17.992 | 15.300 | 1.882.231 | NA | 26.997 |
| 1977 | 19.999 | 16.717 | 2.109.500 | NA | 29.825 |
| 1978 | 22.500 | 18.710 | 2.291.002 | 2.324 | 33.304 |
| 1979 | 26.260 | 23.120 | 2.664.913 | NA | 38.226 |
| 1980 | 30.788 | NA | 3.142.256 | NA | 44.505 |
| 1981 | 36.805 | 26.196 | 3.629.793 | 3.793 | 51.810 |
| 1982 | 43.351 | NA | 4.039.018 | NA | 57.995 |
| 1983 | 48.098 | 30,060 | 4,560.127 | 4,163 | 63.405 |
| 1984 | 54.000 | NA | 5.136.034 | NA | 71,471 |
| 1985 | NA | NA | NA | NA | 78.181 |
| 1986 (Est.) | NA | NA | NA | NA | 85.660 |
| 1987 (Est.) | NA | NA | NA | NA | 90.700 |
| | | | R&D funded by industry — Millions national currency | | |
| 1970 | 5.465 | 7.419 | 792.970 | 453 | 10,444 |
| 1971 | 6.094 | 8.594 | 896.451 | NA | 10.822 |
| 1972 | 6.801 | 8.915 | 1.056.949 | 575 | 11.710 |
| 1973 | 7.578 | 9.357 | 1.319.172 | NA | 13.293 |
| 1974 | 8.770 | 10.095 | 1.626.151 | NA | 14.878 |
| 1975 | 10.235 | 11.514 | 1.715.734 | 823 | 15.820 |
| 1976 | 12,347 | 12.220 | 1.924.345 | NA | 17,694 |
| 1977 | 13.633 | 13.596 | 2.138.892 | NA | 19.629 |
| 1978 | NA | 14.980 | 2.330.556 | 1.552 | 22.450 |
| 1979 | 19.019 | 18.540 | 2.697.945 | 1.484 | 26.081 |
| 1980 | 22.269 | NA | 3.194.604 | NA | 30.911 |
| 1981 | 25.562 | 21.860 | 3.726.055 | 2.529 | 35.944 |
| 1982 | 31.157 | NA | 4.160.607 | NA | 40.096 |
| 1983 | 35.525 | 25.144 | 4.678.482 | 2.869 | 43.514 |
| 1984 | 39.200 | NA | 5.278.564 | NA | 48.821 |
| 1985 | 43.850 | 29.841 | 6.125.416 | 3.757 | 52.569 |
| 1986 (Est.) | NA | NA | NA | NA | 55.699 |
| 1987 (Est.) | NA | NA | NA | NA | 58.770 |
| | | | Gross domestic expenditures on R&D — Millions national currency | | |
| 1970 | 14.956 | 13.903 | 1.355.505 | NA | 26.134 |
| 1971 | 16.621 | 16.527 | 1.532.372 | NA | 26.676 |
| 1972 | 18.277 | 18.212 | 1.791.879 | 1.350 | 28.477 |
| 1973 | 19.789 | 19.232 | 2.215.837 | NA | 30.718 |
| 1974 | 23.031 | 20.990 | 2.716.032 | NA | 32.864 |
| 1975 | 26.203 | 22.968 | 2.974.573 | 2.300 | 35.213 |
| 1976 | 29.774 | 24.150 | 3.320.288 | NA | 39.018 |
| 1977 | 33.185 | 25.733 | 3.651.319 | NA | 42 783 |
| 1978 | 37.671 | 28.900 | 4.045.864 | 3.680 | 48.129 |
| 1979 | 44.123 | 33.457 | 4.583.630 | NA | 54.933 |
| 1980 | 51.014 | 35.903 | 5.246.247 | NA | 62.593 |
| 1981 | 62.471 | 37.703 | 5.892.356 | 6.134 | 71.840 |
| 1982 | 71.836 | 41.300 | 6.528.701 | NA | 79.328 |
| 1983 | 84.671 | 42.512 | 7.180.781 | 6.820 | 87.204 |
| 1984 | 96.198 | 44.200 | 7.893.931 | NA | 97.639 |
| 1985 | 105.917 | 49.000 | 8.890.299 | 8.150 | 107.642 |
| 1986 (Est.) | 117.000 | 53.400 | NA | NA | 116.793 |
| 1987 (Est.) | NA | NA | NA | NA | 124.250 |

SOURCES United States National Science Foundation. *National Patterns of Science and Technology Resources 1987* (forthcoming). other countries OECD Science. Technology and Industry Indicators Division unpublished data

See figure 6-1

## Appendix table 6-2. Expenditures for industrial R&D, by source of funds: 1960-87

| Year | Current dollars | | | Constant 1982 dollars[1] | | |
|---|---|---|---|---|---|---|
| | Total | Company[2] | Federal Government[3] | Total | Company[2] | Federal Government[3] |
| | Millions of dollars | | | | | |
| 1960 | $10,509 | $4,428 | $6,081 | $33,955 | $14,307 | $19,648 |
| 1961 | 10,908 | 4,668 | 6,240 | 34,917 | 14,942 | 19,974 |
| 1962 | 11,464 | 5,029 | 6,435 | 35,892 | 15,745 | 20,147 |
| 1963 | 12,630 | 5,360 | 7,270 | 38,981 | 16,543 | 22,438 |
| 1964 | 13,512 | 5,792 | 7,720 | 41,032 | 17,589 | 23,444 |
| 1965 | 14,185 | 6,445 | 7,740 | 41,992 | 19,079 | 22,913 |
| 1966 | 15,548 | 7,216 | 8,332 | 44,474 | 20,641 | 23,833 |
| 1967 | 16,385 | 8,020 | 8,365 | 45,590 | 22,315 | 23,275 |
| 1968 | 17,429 | 8,869 | 8,560 | 46,194 | 23,506 | 22,688 |
| 1969 | 18,308 | 9,857 | 8,451 | 46,023 | 24,779 | 21,244 |
| 1970 | 18,067 | 10,288 | 7,779 | 42,986 | 24,478 | 18,508 |
| 1971 | 18,320 | 10,654 | 7,666 | 41,280 | 24,006 | 17,274 |
| 1972 | 19,552 | 11,535 | 8,017 | 42,056 | 24,812 | 17,245 |
| 1973 | 21,249 | 13,104 | 8,145 | 42,893 | 26,451 | 16,441 |
| 1974 | 22,887 | 14,667 | 8,220 | 42,415 | 27,181 | 15,234 |
| 1975 | 24,187 | 15,582 | 8,605 | 40,781 | 26,272 | 14,509 |
| 1976 | 26,997 | 17,436 | 9,561 | 42,805 | 27,645 | 15,159 |
| 1977 | 29,825 | 19,340 | 10,485 | 44,330 | 28,746 | 15,584 |
| 1978 | 33,304 | 22,115 | 11,189 | 46,115 | 30,622 | 15,493 |
| 1979 | 38,226 | 25,708 | 12,518 | 48,652 | 32,720 | 15,932 |
| 1980 | 44,505 | 30,476 | 14,029 | 51,919 | 35,553 | 16,366 |
| 1981 | 51,810 | 35,428 | 16,382 | 55,140 | 37,705 | 17,435 |
| 1982 | 57,995 | 39,512 | 18,483 | 57,995 | 39,512 | 18,483 |
| 1983 | 63,403 | 42,861 | 20,542 | 61,047 | 41,268 | 19,779 |
| 1984 | 71,471 | 48,308 | 23,163 | 66,343 | 44,842 | 21,501 |
| 1985 (Prel.) | 78,181 | 51,696 | 26,485 | 70,326 | 46,502 | 23,824 |
| 1986 (Est.) | 85,660 | 54,724 | 30,936 | 75,107 | 47,982 | 27,125 |
| 1987 (Est.) | 90,700 | 57,700 | 33,000 | 76,956 | 48,956 | 27,999 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

[2] Includes all sources other than the Federal Government

[3] Data include federally funded R&D centers administered by industry

Note Detail may not add to totals because of rounding

SOURCES 1960-64: National Science Foundation, *National Patterns of Science and Technology Resources 1981* (NSF 81-311), p 21. 1965-84 National Science Foundation, *National Patterns of Science and Technology Resources 1984* (NSF 84-311), p 28 1985-87 National Science Foundation Division of Science Resources Studies, Industry Studies Group, unpublished data

See figures 6-2 and O-28 in Overview

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3 : :

## Appendix table 6-3. Expenditures for industrial R&D, by industry: 1960-1985

| Industry | 1960 | 1962 | 1964 | 1966 | 1968 | 1970 | 1972 | 1974 | 1975 | 1976 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | | | | | | | | | | | |
| Total | $10,509 | $11.464 | $13.512 | $15.548 | $17.429 | $18.067 | $19.552 | $22.887 | $24.187 | $26.997 | $33.304 | $38.226 | $44.505 | $51.810 | $57.996 | $63.403 | $71.471 | $78.181 |
| All high-technology manufacturing industries | 8.304 | 9,079 | 10.680 | 12.244 | 13.583 | 13.685 | 14,558 | 16.799 | 17.914 | 19.810 | 23,904 | 27.233 | 31.939 | 38.354 | 43.813 | 47.926 | 54.26? | 59.666 |
| Chemicals and allied products (SIC 28) | 980 | 1.175 | 1,284 | 1,407 | 1.589 | 1.773 | 1,932 | 2.450 | 2.727 | 3.017 | 3.580 | 4,038 | 4.636 | 5.625 | 6.659 | 7.293 | 8.028 | 8.667 |
| Machinery (including computers) (SIC 35) | 949 | 914 | 1.015 | 1.217 | 1.483 | 1.729 | 2.158 | 2.985 | 3,196 | 3,487 | 4,283 | 4.825 | 5.901 | 6,818 | 7.835 | 8.386 | 9.667 | 10.870 |
| Electrical equipment (SIC 36) | 2.532 | 2.639 | 2,972 | 3.626 | 4.083 | 4,220 | 4.680 | 5.011 | 5.105 | 5.636 | 6,507 | 7.824 | 9,175 | 10.329 | 11.642 | 13.950 | 15.694 | 17.080 |
| Aircraft and missiles (SIC 372, 376) | 3,514 | 4.042 | 5.078 | 5.526 | 5.765 | 5.219 | 4,950 | 5.278 | 5.713 | 6,339 | 7,536 | 8.041 | 9,198 | 11.968 | 13,658 | 13.853 | 16.033 | 17.619 |
| Professional and scientific instruments (SIC 38) | 329 | 309 | 331 | 468 | 663 | 744 | 838 | 1.075 | 1.173 | 1.331 | 1,998 | 2.505 | 3,029 | 3.614 | 4.019 | 4,444 | 4,840 | 5.430 |
| All other manufacturing industries | 2.037 | 2,151 | 2.513 | 2.807 | 3.243 | 3.677 | 4.287 | 5.320 | 5.538 | 6.342 | 8.171 | 9.453 | 10,751 | 11.550 | 12.178 | 13.288 | 14.624 | 15.664 |
| Food, kindred, and tobacco products (SIC 20, 21) | 104 | 121 | 144 | 164 | 184 | 230 | 259 | 298 | 335 | 355 | 472 | 528 | 620 | 719 | 780 | 876 | 1.001 | 1,042 |
| Textiles and apparel (SIC 22, 23) | 38 | 28 | 32 | 51 | 58 | 58 | 61 | 69 | 70 | 82 | 89 | 101 | 115 | 124 | 130 | 144 | 139 | 150 |
| Lumber, wood products, and furniture (SIC 24, 25) | 10 | 10 | 12 | 12 | 20 | 52 | 64 | 84 | 88 | 107 | 126 | 139 | 148 | 161 | 162 | 169 | 181 | 172 |
| Paper and allied products (SIC 26) | 56 | 65 | 77 | 117 | 144 | 178 | 189 | 237 | 249 | 313 | 387 | 445 | 495 | 570 | 626 | 747 | 802 | 859 |
| Petroleum refining (SIC 29) | 296 | 310 | 393 | 371 | 437 | 515 | 468 | 622 | 693 | 767 | 1,060 | 1,262 | 1,552 | 1,700 | 2,100 | 2.229 | 2,177 | 2.106 |
| Rubber products (SIC 30) | 121 | 141 | 158 | 168 | 223 | 276 | 377 | 469 | 467 | 502 | 493 | 577 | 656 | 800 | 850 | 818 | 884 | 1.147 |
| Stone, clay, and glass products (SIC 32) | 88 | 96 | 109 | 117 | 142 | 167 | 183 | 217 | 233 | 263 | 324 | 356 | 406 | 470 | 500 | 491 | 476 | 486 |
| Primary metals (SIC 33) | 177 | 171 | 195 | 232 | 251 | 275 | 277 | 358 | 443 | 506 | 560 | 634 | 728 | 878 | 1.000 | 1,115 | 715 | 730 |
| Fabricated metal products (SIC 34) | 145 | 146 | 148 | 154 | 183 | 207 | 253 | 313 | 324 | 358 | 384 | 455 | 550 | 624 | 568 | 604 | 716 | 624 |
| Motor vehicles (SIC 371) | 884 | 999 | 1,182 | 1,344 | 1.499 | 1.591 | 1,954 | 2,389 | 2,340 | 2,778 | 3,879 | 4,509 | 4,955 | 4,806 | 4.807 | 5,337 | 6.090 | 7,058 |
| Other manufacturing industries | 118 | 64 | 63 | 77 | 102 | 128 | 202 | 264 | 296 | 311 | 397 | 447 | 526 | 698 | 655 | 758 | 1,443 | 1.290 |
| Nonmanufacturing industries | 168 | 234 | 319 | 497 | 603 | 705 | 707 | 768 | 735 | 845 | 1.229 | 1,540 | 1,815 | 1.906 | 2.005 | 2,189 | 2.585 | 2.851 |

(continued)

## Appendix table 6-3. (Continued)

| Industry | 1960 | 1962 | 1964 | 1966 | 1968 | 1970 | 1972 | 1974 | 1975 | 1976 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions constant 1982 dollars[1] | | | | | | | | | | | | | | | | | |
| Total | $33.955 | $35.892 | $41.032 | $44 474 | $46 194 | $42 986 | $42.056 | $42.415 | $40.781 | $42.805 | $46.115 | $48.652 | $51.919 | $55.140 | $57.996 | $61,047 | $66.343 | $70.326 |
| All high-technology manufacturing industries | 26.830 | 28.425 | 32.432 | 35 023 | 36,001 | 32,560 | 31 314 | 31 132 | 30.204 | 31.410 | 33.099 | 34.661 | 37.260 | 40,819 | 43.813 | 46.145 | 50.369 | 53.671 |
| Chemicals and allied products (SIC 28) | 3.166 | 3.679 | 3.899 | 4 025 | 4.212 | 4.218 | 4.156 | 4.540 | 4.598 | 4.784 | 4.957 | 5.139 | 5.408 | 5.987 | 6.659 | 7.022 | 7.452 | 7.796 |
| Machinery (including computers) (SIC 35) | 3.066 | 2.962 | 3.082 | 3.481 | 3.931 | 4.114 | 4.642 | 5.532 | 5.389 | 5.529 | 5.930 | 6.141 | 6.884 | 7.256 | 7.835 | 8.074 | 8.973 | 9.778 |
| Electrical equipment (SIC 36) | 8.181 | 8.262 | 9.025 | 10.372 | 10.822 | 10,040 | 10.067 | 9.287 | 8.607 | 8.936 | 9.010 | 9.958 | 10.703 | 10.993 | 11.642 | 13.432 | 14.568 | 15.364 |
| Aircraft and missiles (SIC 372, 376) | 11.354 | 12.655 | 15.421 | 15.807 | 15.280 | 12.417 | 10.647 | 9.781 | 9.632 | 10.051 | 10 435 | 10.234 | 10,730 | 12.737 | 13.658 | 13.338 | 14.883 | 15.849 |
| Professional and scientific instruments (SIC 38) | 1.063 | 967 | 1.005 | 1.339 | 1.757 | 1.770 | 1.803 | 1.992 | 1.978 | 2.110 | 2.767 | 3,188 | 3.534 | 3.846 | 4.019 | 4.279 | 4.493 | 4.884 |
| All other manufacturing industries | 6.582 | 6.735 | 7.631 | 8.029 | 8.595 | 8.749 | 9.221 | 9.859 | 9.337 | 10.055 | 11.314 | 12 031 | 12.542 | 12.292 | 12.178 | 12.794 | 13.575 | 14.090 |
| Food, kindred, and tobacco products (SIC 20, 21) | 336 | 379 | 437 | 469 | 488 | 547 | 557 | 552 | 565 | 563 | 654 | 672 | 723 | 765 | 780 | 843 | 929 | 937 |
| Textiles and apparel (SIC 22, 23) | 123 | 88 | 97 | 146 | 154 | 138 | 131 | 128 | 118 | 130 | 123 | 129 | 134 | 132 | 130 | 139 | 129 | 135 |
| Lumber, wood products, and furniture (SIC 24, 25) | 32 | 31 | 36 | 34 | 53 | 124 | 138 | 156 | 148 | 170 | 174 | 177 | 173 | 171 | 162 | 163 | 168 | 155 |
| Paper and allied products (SIC 26) | 181 | 204 | 234 | 335 | 382 | 424 | 407 | 439 | 420 | 496 | 536 | 566 | 577 | 607 | 626 | 719 | 744 | 773 |
| Petroleum refining (SIC 29) | 956 | 971 | 1.193 | 1.061 | 1.158 | 1,225 | 1.007 | 1.153 | 1.168 | 1.216 | 1.468 | 1.606 | 1.811 | 1.809 | 2.100 | 2.146 | 2.021 | 1.894 |
| Rubber products (SIC 30) | 391 | 441 | 480 | 481 | 591 | 657 | 811 | 869 | 787 | 796 | 683 | 734 | 765 | 851 | 850 | 788 | 821 | 1.032 |
| Stone, clay, and glass products (SIC 32) | 284 | 301 | 331 | 335 | 376 | 397 | 394 | 402 | 393 | 417 | 449 | 453 | 474 | 500 | 500 | 473 | 442 | 437 |
| Primary metals (SIC 33) | 572 | 535 | 592 | 664 | 665 | 654 | 596 | 663 | 747 | 802 | 775 | 807 | 849 | 934 | 1,000 | 1,074 | 664 | 657 |
| Fabricated metal products (SIC 34) | 468 | 457 | 449 | 441 | 485 | 493 | [illegible] | 580 | 546 | 568 | 532 | 579 | 642 | 664 | 568 | 582 | 665 | 561 |
| Motor vehicles (SIC 371) | 2.856 | 3.128 | 3.589 | 3.844 | 3.973 | 3.785 | 4,203 | 4.427 | 3.945 | 4.405 | 5.371 | 5.739 | 5.780 | 5.115 | 4.807 | 5,139 | 5.653 | 6.349 |
| Other manufacturing industries | 381 | 200 | 191 | 220 | 270 | 305 | 435 | 489 | 499 | 493 | 550 | 569 | 614 | 743 | 655 | 730 | 1.339 | 1.160 |
| Nonmanufacturing industries | 543 | 733 | 969 | 1,422 | 1.598 | 1,677 | 1.521 | 1.423 | 1.239 | 1,340 | 1.702 | 1.960 | 2.117 | 2.029 | 2.005 | 2.108 | 2.400 | 2.565 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

SOURCE National Science Foundation, *Research and Development in Industry* (annual series)

See figures 6-3 and O-29 in Overview

## Appendix table 6-4. Total employment of R&D-performing companies, by industry: 1960-1985

| Industry | 1960 | 1962 | 1964 | 1966 | 1968 | 1970 | 1972 | 1974 | 1975 | 1976 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Thousands | | | | | | | | | | | | | | | | | |
| Total | 11.634 | 11.404 | 11.561 | 13.383 | 14,425 | 14,443 | 14.090 | 14.085 | 13.455 | 14.088 | 14.897 | 15.549 | 17.276 | 17.210 | 15.596 | 15.229 | 15.605 | 15.229 |
| All high-technology manufacturing industries | 4.637 | 4.807 | 4.843 | 5.890 | 6.480 | 6.623 | 6.286 | 6.403 | 6.120 | 6.000 | 6,417 | 6,734 | 7,260 | 7,419 | 6.485 | 6,442 | 6.791 | 6.752 |
| Chemicals and allied products (SIC 28) | 862 | 948 | 954 | 1.036 | 1.145 | 1.065 | 1.052 | 1,091 | 1.088 | 1.124 | 1.164 | 1.224 | 1.278 | 1.311 | 1.281 | 1.243 | 1.240 | 1.263 |
| Machinery (including computers) (SIC 35) | 1.249 | 1.176 | 1.140 | 1.351 | 1.492 | 1.528 | 1.483 | 1.547 | 1.508 | 1.470 | 1.563 | 1.649 | 1.847 | 2.077 | 1.690 | 1.495 | 1.557 | 1.527 |
| Electrical equipment (SIC 36, 48) | 1.362 | 1.412 | 1.582 | 2,135 | 2.203 | 2.355 | 2.319 | 2.286 | 2,081 | 1.984 | 2.180 | 2.250 | 2.286 | 2.240 | 1.963 | 2.173 | 2.430 | 2,357 |
| Aircraft and missiles (SIC 372, 376) | 884 | 962 | 898 | 1,026 | 1.241 | 1.164 | 965 | 988 | 971 | 927 | 974 | 1.039 | 987 | 949 | 940 | 906 | 947 | 987 |
| Professional and scientific instruments (SIC 38) | 280 | 309 | 269 | 342 | 399 | 511 | 467 | 491 | 472 | 495 | 536 | 572 | 862 | 842 | 611 | 625 | 617 | 618 |
| All other manufacturing industries | 5.762 | 5.735 | 5.832 | 6.446 | 6.726 | 7.254 | 7.258 | 7.110 | 6,745 | 7.265 | 7.566 | 7,884 | 8,120 | 7.762 | 7.168 | 6.878 | 7.097 | 6.893 |
| Food, kindred, and tobacco products (SIC 20, 21) | 737 | 784 | 837 | 774 | 779 | 920 | 987 | 951 | 955 | 930 | 921 | 958 | 1.332 | 1,298 | 1.291 | 1.195 | 1,346 | 1.312 |
| Textiles and apparel (SIC 22, 23) | 388 | 376 | 382 | 538 | 633 | 606 | 602 | 600 | 562 | 633 | 608 | 611 | 715 | 628 | 529 | 538 | 531 | 497 |
| Lumber, wood products, and furniture (SIC 24, 25) | 117 | 99 | 112 | 157 | 201 | 244 | 258 | 254 | 254 | 302 | 335 | 336 | 290 | 296 | 279 | 273 | 288 | 290 |
| Paper and allied products (SIC 26) | 361 | 402 | 406 | 448 | 473 | 631 | 652 | 592 | 568 | 527 | 523 | 528 | 537 | 522 | 518 | 504 | 507 | 487 |
| Petroleum refining (SIC 29) | 526 | 506 | 578 | 617 | 627 | 554 | 530 | 469 | 480 | 513 | 526 | 529 | 703 | 716 | 672 | 622 | 618 | 566 |
| Rubber products (SIC 30) | 267 | 283 | 309 | 341 | 355 | 381 | 368 | 376 | 343 | 439 | 439 | 445 | 393 | 363 | 360 | 399 | 430 | 406 |
| Stone, clay, and glass products (SIC 32) | na | 330 | 335 | 363 | 392 | 361 | 348 | 345 | 333 | 404 | 401 | 420 | 434 | 405 | 356 | 342 | 349 | 342 |
| Primary metals (SIC 33) | 1,036 | 1,022 | 1,016 | 1,124 | 1,110 | 1,090 | 1,049 | 1,072 | 1,010 | 1,056 | 1,097 | 1.118 | 1.068 | 1,018 | 880 | 758 | 714 | 673 |
| Fabricated metal products (SIC 34) | 407 | 455 | 422 | 476 | 514 | 689 | 687 | 707 | 677 | 601 | 643 | 669 | 570 | 551 | 499 | 449 | 471 | 436 |
| Motor vehicles and other transportation equipment (SIC 371, 373-5, 379) | 1.146 | 1.080 | 1.149 | 1.264 | 1.292 | 1.350 | 1.308 | 1.279 | 1.120 | 1.283 | 1.434 | 1.472 | 1.381 | 1.232 | 1.093 | 1.111 | 1,203 | 1.218 |
| Other manufacturing industries (SIC 27, 31, 39) | 777 | 398 | 286 | 344 | 350 | 428 | 469 | 465 | 443 | 577 | 639 | 798 | 697 | 733 | 691 | 687 | 640 | 667 |
| Nonmanufacturing industries | 1.235 | 862 | 886 | 1,048 | 1.219 | 566 | 546 | 572 | 602 | 824 | 914 | 931 | 1.898 | 2,028 | 1.945 | 1.908 | 1,841 | 1.782 |

SOURCE: National Science Foundation, *Research and Development in Industry* (annual series)

See figure 6-4

Science & Engineering Indicators—1987

## Appendix table 6-5. Federal funding of industrial R&D, for selected industries: 1980-85

| Industry | 1980 | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| | Millions of dollars | | | |
| Total | $14.029 | $20,542 | $23,163 | $26,485 |
| Chemicals and allied products (SIC 28) | 372 | 448 | 232 | 316 |
| Industrial chemicals (SIC 281-2, 286) | 341 | 440 | 223 | 298 |
| Petroleum refining (SIC 29) | 151 | NA | NA | NA |
| Primary metals (SIC 33) | 135 | 392 | NA | NA |
| Ferrous metals and products (SIC 331-2, 3398-99) | 105 | NA | NA | NA |
| Nonferrous metals and products (SIC 333-6) | 30 | NA | 32 | 41 |
| Fabricated metal products (SIC 34) | 49 | 62 | 61 | 42 |
| Machinery (including computers) (SIC 35) | 647 | 1,131 | 1,216 | 1,536 |
| Electrical equipment (SIC 36) | 3,744 | 5,286 | 5,956 | 6,887 |
| Radio and TV receiving equipment (SIC 365) | 210 | NA | NA | NA |
| Communication equipment (SIC 366) | 1,657 | 2,572 | 3.114 | 3,606 |
| Electronic components (SIC 367) | 382 | 346 | 452 | 520 |
| Other electrical equipment (SIC 361-4, 369) | 1,495 | NA | NA | NA |
| Motor vehicles and motor vehicle equipment (SIC 371) | 655 | 566 | 677 | 978 |
| Aircraft and missiles (SIC 372, 376) | 6,628 | 10,405 | 12,228 | 13,421 |
| Professional and scientific instruments (SIC 38) | 573 | 639 | 660 | 707 |
| Scientific and mechanical measuring instruments (SIC 381-2) | 350 | NA | NA | NA |
| Optical, surgical, photographic, and other instruments (SIC 383-7) | 223 | NA | NA | NA |
| Nonmanufacturing industries | 779 | 1,022 | 1,224 | NA |
| | Millions of constant 1982[1] dollars | | | |
| Total | $16,366 | $19,779 | $21,501 | $23,824 |
| Chemicals and allied products (SIC 28) | 434 | 431 | 215 | 284 |
| Industrial chemicals (SIC 281-2, 286) | 398 | 424 | 207 | 268 |
| Petroleum refining (SIC 29) | 176 | NA | NA | NA |
| Primary metals (SIC 33) | 157 | 377 | NA | NA |
| Ferrous metals and products (SIC 331-2, 3398-99) | 122 | NA | NA | NA |
| Nonferrous metals and products (SIC 333-6) | 35 | NA | 30 | 37 |
| Fabricated metal products (SIC 34) | 57 | 60 | 57 | 38 |
| Machinery (including computers) (SIC 35) | 755 | 1,089 | 1,129 | 1,382 |
| Electrical equipment (SIC 36) | 4,368 | 5,090 | 5,529 | 6,195 |
| Radio and TV receiving equipment (SIC 365) | 245 | NA | NA | NA |
| Communication equipment (SIC 366) | 1,933 | 2,476 | 2,891 | 3,244 |
| Electronic components (SIC 367) | 446 | 333 | 420 | 468 |
| Other electrical equipment (SIC 361-4, 369) | 1,744 | NA | NA | NA |
| Motor vehicles and motor vehicle equipment (SIC 371) | 764 | 545 | 628 | 880 |
| Aircraft and missiles (SIC 372, 376) | 7,732 | 10,018 | 11,351 | 12,073 |
| Professional and scientific instruments (SIC 38) | 668 | 615 | 613 | 636 |
| Scientific and mechanical measuring instruments (SIC 381-2) | 408 | NA | NA | NA |
| Optical, surgical, photographic, and other instruments (SIC 383-7) | 260 | NA | NA | NA |
| Nonmanufacturing industries | 909 | 984 | 1,136 | NA |

[1] GNP implicit price deflator used to convert current dollars to constant dollars.

SOURCE: National Science Foundation. *Research and Development in Industry* (annual series)

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## Appendix table 6-6. Company funds for research and development by industry: 1970-87

| | 1970 | 1972 | 1974 | 1976 | 1978 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986[1] | 1987[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | | | | | | |
| Total | $10.283 | $11,535 | $14.667 | $17.436 | $22.115 | $30.476 | $35.428 | $39,512 | $42.861 | $48.308 | $51.696 | $54.724 | $59,500 |
| All high-technology manufacturing industries | 6.833 | 7,468 | 9.599 | 11.373 | 14.383 | 19.975 | 24.156 | 27.529 | 30.016 | 33.971 | 36.802 | 39.363 | 42.800 |
| Chemicals and allied products (SIC 28) | 1.593 | 1.741 | 2.236 | 2.751 | 3.250 | 4.264 | 5.205 | 6.226 | 6.845 | 7.797 | 8.352 | 9.190 | 9.600 |
| Machinery (including computers) (SIC 35) | 1.469 | 1.758 | 2.473 | 2.955 | 3.901 | 5.254 | 6.124 | 6.977 | 7.254 | 8.452 | 9.334 | 10.200 | 10.800 |
| Electrical equipment (SIC 36) | 2.008 | 2,313 | 2.704 | 3,081 | 3.741 | 5.431 | 6.409 | 7.048 | 8.664 | 9.738 | 10.194 | 10.222 | 12.500 |
| Aircraft and missiles (SIC 372. 376) | 1.213 | 978 | 1.278 | 1.418 | 1,823 | 2.570 | 3.440 | 3.882 | 3.448 | 3.804 | 4,198 | 4.751 | 4.600 |
| Professional and scientific instruments (SIC 38) | 550 | 678 | 908 | 1.168 | 1.668 | 2.456 | 2.978 | 3.396 | 3.805 | 4.180 | 4.724 | 5.000 | 5.300 |
| All other manufacturing industries | 3.225 | 3.790 | 4.763 | 5.592 | 7.030 | 9.464 | 10.224 | 10.882 | 11.678 | 12.967 | NA | NA | NA |
| Food. kindred. and tobacco products (SIC 20. 21) | 222 | 258 | 297 | NA | NA | NA | 636 | 762 | 766 | 1.001 | 1.042 | NA | NA |
| Textiles and apparel (SIC 22. 23) | NA | 61 | NA | NA | NA | NA | 116 | 124 | 125 | 139 | 150 | NA | NA |
| Lumber, wood products. and furniture (SIC 24. 25) | 52 | NA | NA | 106 | 126 | 148 | 161 | 162 | 169 | 181 | 172 | NA | NA |
| Paper and allied products (SIC 26) | NA | NA | NA | NA | NA | 495 | 566 | 626 | 674 | 802 | 859 | NA | NA |
| Petroleum refining (SIC 29) | 493 | 454 | 603 | 715 | 939 | 1,401 | 1.780 | 1.981 | 2.030 | 2.177 | 2.106 | NA | NA |
| Rubber products (SIC 30) | 205 | 255 | NA | NA | NA | NA | 598 | 665 | 743 | 884 | 834 | NA | NA |
| Stone. clay. and glass products (SIC 32) | 156 | 168 | NA | NA | NA | 363 | 411 | 414 | 451 | 476 | 486 | NA | NA |
| Primary metals (SIC 33) | 265 | 264 | 350 | 481 | 497 | 594 | 702 | 721 | 722 | 715 | 730 | NA | NA |
| Fabricated metal products (SIC 34) | 201 | 243 | 299 | 322 | 348 | 501 | 545 | 510 | 542 | 654 | 582 | NA | NA |
| Motor vehicles and other transportation equipment (SIC 371. 373-5. 379) | 1.278 | 1,690 | 2.141 | 2.395 | 3.381 | 4,388 | 4.299 | 4,425 | 4,931 | 5,565 | 6.218 | 6,600 | 6,600 |
| Other manufacturing industries | NA | NA | NA | 212 | 266 | 339 | 410 | 492 | 525 | 373 | NA | NA | NA |
| Nonmanufacturing industries | 225 | 277 | 305 | 471 | 702 | 1,037 | 1,048 | 1.101 | 1.167 | 1.370 | 1.366 | NA | NA |

(continued)

## Appendix table 6-6. (Continued)

| | 1970 | 1972 | 1974 | 1976 | 1978 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986[1] | 1987[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions of constant 1982 dollars[2] | | | | | | | | | | | | |
| Total | $24,466 | $24.812 | $27.181 | $27.645 | $32.870 | $35.553 | $37,705 | $39,512 | $41.268 | $44.842 | $46,502 | $47.982 | $50.484 |
| All high-technology manufacturing industries | 16,257 | 16.064 | 17,789 | 18,032 | 21,378 | 23,303 | 25,709 | 27,529 | 28,900 | 31,533 | 33,104 | 34,514 | 36.314 |
| Chemicals and allied products (SIC 28) | 3,790 | 3,745 | 4,144 | 4.362 | 4,831 | 4,974 | 5.540 | 6.226 | 6,591 | 7.238 | 7 513 | 8,058 | 8,145 |
| Machinery (including computers) (SIC 35) | 3.495 | 3,781 | 4,583 | 4,685 | 5,798 | 6,129 | 6,518 | 6.977 | 6.984 | 7,846 | 8.396 | 8.943 | 9.163 |
| Electrical equipment (SIC 36) | 4,778 | 4.975 | 5,011 | 4.885 | 5.560 | 6,336 | 6.821 | 7.048 | 8.342 | 9.039 | 9.170 | 8.963 | 10.606 |
| Aircraft and missiles (SIC 372, 376) | 2.886 | 2.104 | 2,368 | 2.248 | 2.710 | 2.998 | 3.661 | 3.882 | 3.320 | 3,531 | 3.776 | 4.166 | 3.903 |
| Professional and scientific instruments (SIC 38) | 1.309 | 1,458 | 1,683 | 1.852 | 2.479 | 2.865 | 3,169 | 3.396 | 3.664 | 3,880 | 4.249 | 4.384 | 4,497 |
| All other manufacturing industries | 7.673 | 8,152 | 8.827 | 8.866 | 10.449 | 11.041 | 10.881 | 10.882 | 11.244 | 12.037 | NA | NA | NA |
| Food, kindred, and tobacco products (SIC 20, 21) | 528 | 555 | 550 | NA | NA | NA | 677 | 762 | 738 | 929 | 937 | NA | NA |
| Textiles and apparel (SIC 22, 23) | NA | 131 | NA | NA | NA | NA | 123 | 124 | 120 | 129 | 135 | NA | NA |
| Lumber, wood products, and furniture (SIC 24, 25) | 124 | NA | NA | 168 | 187 | 173 | 171 | 162 | 163 | 168 | 155 | NA | NA |
| Paper and allied products (SIC 26) | NA | NA | NA | NA | NA | 577 | 602 | 626 | 649 | 744 | 773 | NA | NA |
| Petroleum refining (SIC 29) | 1,173 | 977 | 1,117 | 1,134 | 1,396 | 1,634 | 1.894 | 1.981 | 1.955 | 2.021 | 1.894 | NA | NA |
| Rubber products (SIC 30) | 488 | 549 | NA | NA | NA | NA | 636 | 665 | 715 | 821 | 750 | NA | NA |
| Stone, clay, and glass products (SIC 32) | 371 | 361 | NA | NA | NA | 423 | 437 | 414 | 434 | 442 | 437 | NA | NA |
| Primary metals (SIC 33) | 631 | 568 | 649 | 763 | 739 | 693 | 747 | 721 | 695 | 664 | 657 | NA | NA |
| Fabricated metal products (SIC 34) | 478 | 523 | 554 | 511 | 517 | 584 | 580 | 510 | 522 | 607 | 524 | NA | NA |
| Motor vehicles and other transportation equipment (SIC 371, 373-5, 379) | 3,041 | 3.635 | 3.968 | 3,797 | 5,025 | 5.119 | 4,575 | 4,425 | 4.748 | 5,166 | 5,593 | 5,787 | 5.600 |
| Other manufacturing industries | NA | NA | NA | 336 | 395 | 395 | 436 | 492 | 505 | 346 | NA | NA | NA |
| Nonmanufacturing industries | 535 | 596 | 565 | 747 | 1,043 | 1,210 | 1,115 | 1,101 | 1,124 | 1.272 | 1.229 | NA | NA |

[1] Estimated

[2] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

Note: Detail may not add to totals because of rounding

SOURCE: National Science Foundation, *Research and Development in Industry* (annual series)

## Appendix table 6-7. Share of R&D funding provided by the Federal Government in selected industries: 1980-85

| Industry | 1980 | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| | Percent | | | |
| Total | 31.5 | 32.4 | 32.4 | 33.9 |
| Chemicals and allied products (SIC 28) | 8.0 | 6.1 | 2.9 | 3.6 |
| Petroleum refining (SIC 29) | 9.7 | NA | NA | NA |
| Primary metals (SIC 33) | 18.5 | 35.2 | NA | NA |
| Fabricated metal products (SIC 34) | 8.9 | 10.3 | 8.5 | 6.7 |
| Machinery (including computers) (SIC 35) | 11.0 | 13.5 | 12.6 | 14.1 |
| Electrical equipment (SIC 36) | 40.8 | 37.9 | 38.0 | 40.3 |
| Aircraft and missiles (SIC 372, 376) | 72.0 | 75.1 | 76.3 | 76.2 |
| Professional and scientific instruments (SIC 38) | 18.9 | 14.4 | 13.6 | 13.C |
| Nonmanufacturing industries | 42.9 | 46.7 | 47.9 | NA |

Note. NA - Not Available.

SOURCE: See appendix tables 6-5, 6-6

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## Appendix table 6-8. U.S. patents granted, by nationality of inventor: 1970-86

| | By date of grant | | | | | | | | By date of application | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inventors from: | | | | | | | | Inventors from: | | | | | | |
| | All U.S. patents | United States | All other countries | Japan | West Germany | United Kingdom | France | Other countries | All U.S. patents | United States | All other countries | Japan | West Germany | United Kingdom | France | Other countries |
| 1970 | 64,429 | 47,077 | 17,352 | 2,625 | 4,435 | 2,954 | 1,731 | 5,607 | 65,944 | 45,852 | 20,092 | 4,370 | 5,029 | 2,726 | 1,854 | 6,113 |
| 1971 | 78,317 | 55,984 | 22,333 | 4,029 | 5,522 | 3,464 | 2,214 | 7,104 | 66,368 | 45,591 | 20,777 | 4,756 | 4,997 | 2,580 | 2,022 | 6,422 |
| 1972 | 74,551 | 51,349 | 23,202 | 5,129 | 5,709 | 3,149 | 2,219 | 6,996 | 63,372 | 42,446 | 20,926 | 4,588 | 5,048 | 2,668 | 2,113 | 6,509 |
| 1973 | 74,143 | 51,500 | 22,643 | 4,939 | 5,587 | 2,855 | 2,144 | 7,118 | 66,308 | 42,752 | 23,556 | 5,866 | 5,746 | 2,782 | 2,214 | 6,948 |
| 1974 | 76,278 | 50,641 | 25,637 | 5,892 | 6,153 | 3,146 | 2,569 | 7,877 | 66,407 | 41,853 | 24,554 | 6,327 | 5,856 | 2,884 | 2,225 | 7,262 |
| 1975 | 72,000 | 46,715 | 25,285 | 6,352 | 6,036 | 3,043 | 2,367 | 7,487 | 65,846 | 42,226 | 23,620 | 6,074 | 5,460 | 2,668 | 2,151 | 7,267 |
| 1976 | 70,226 | 44,280 | 25,946 | 6,543 | 6,180 | 2,995 | 2,408 | 7,820 | 65,762 | 41,611 | 24,151 | 6,577 | 5,571 | 2,618 | 2,127 | 7,258 |
| 1977 | 65,269 | 41,485 | 23,784 | 6,217 | 5,537 | 2,654 | 2,108 | 7,268 | 65,916 | 40,801 | 25,115 | 7,077 | 5,965 | 2,633 | 2,098 | 7,342 |
| 1978 | 67,002 | 42,154 | 24,848 | 6,911 | 5,850 | 2,722 | 2,119 | 7,246 | 65,524 | 39,590 | 25,934 | 7,473 | 6,186 | 2,518 | 2,271 | 7,486 |
| 1979 | 48,854 | 30,079 | 18,775 | 5,251 | 4,527 | 1,910 | 1,604 | 5,483 | 65,577 | 38,901 | 26,676 | 8,405 | 6,131 | 2,489 | 2,220 | 7,431 |
| 1980 | 61,819 | 37,356 | 24,463 | 7,12[illegible] | 5,747 | 2,406 | 2,088 | 7,098 | 66,119 | 38,688 | 27,431 | 9,527 | 6,162 | 2,359 | 2,289 | 7,094 |
| 1981 | 65,771 | 39,223 | 26,548 | 8,388 | 6,252 | 2,475 | 2,181 | 7,252 | 62,906 | 36,169 | 26,737 | 9,918 | 5,990 | 2,164 | 2,052 | 6,613 |
| 1982[1] | 57,888 | 33,896 | 23,992 | 8,149 | 5,408 | 2,134 | 1,972 | 6,329 | 64,800 | 36,700 | 28,100 | 11,400 | 6,000 | 2,200 | 2,100 | 6,400 |
| 1983[1] | 56,860 | 32,871 | 23,989 | 8,793 | 5,423 | 1,931 | 1,895 | 5,947 | 61,300 | 34,400 | 26,900 | 11,300 | 5,400 | 2,100 | 2,000 | 6,100 |
| 1984[1] | 67,200 | 38,365 | 28,835 | 11,110 | 6,255 | 2,271 | 2,162 | 7,037 | 65,900 | 35,800 | 30,008 | 13,100 | 5,900 | 2,300 | 2,200 | 6,500 |
| 1985[1] | 71,661 | 39,554 | 32,107 | 12,746 | 6,665 | 2,495 | 2,400 | 7,801 | 69,300 | 37,000 | 32,300 | 15,200 | 6,300 | 2,400 | 2,300 | 6,200 |
| 1986[1] | 70,860 | 38,124 | 32,736 | 13,209 | 6,803 | 2,409 | 2,369 | 7,946 | 72,500 | 39,000 | 33,500 | 16,700 | 6,600 | 2,400 | 2,500 | 5,200 |

[1] Data by date of application are estimated

SOURCES: U.S. Department of Commerce, U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast (OTAF), *Special Report: A Profile of U.S. Patent Activity* (1978); OTAF, *Indicators of Patent Output of U.S. Industry, 1963-79* (June, 1980); OTAF, *Indicators of Patent Output of U.S. Industry, 1963-81* (June 1982); OTAF, *Patenting Trends in the United States, 1963-85* (May, 1986); U.S. Department of Commerce, Patent and Trademark Office, *Patenting Trends in the United States, 1963-86* (June, 1987), U.S. Department of Commerce, Patent and Trademark Office, unpublished data

See figures 6-5, 6-7, and O-22 in Overview

## Appendix table 6-9. U.S. patents granted to U.S. inventors, by type of owner: 1970-86

| Year | By date of application | | | | | By date of grant | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All patents | U.S. corp | U.S. Gov't | U.S. individual[1] | Foreign[2] | All patents | U.S. corp. | U.S. Gov't | U.S. individual[1] | Foreign[2] |
| 1970 | 45,852 | 33,104 | 1,624 | 10,869 | 255 | 47,077 | 34,978 | 1,760 | 10,096 | 243 |
| 1971 | 45,584 | 32,627 | 1,595 | 11,105 | 257 | 55,984 | 40,925 | 2,131 | 12,584 | 344 |
| 1972 | 42,446 | 30,578 | 1,513 | 10,151 | 204 | 51,524 | 37,960 | 1,759 | 11,569 | 235 |
| 1973 | 42,752 | 30,573 | 1,391 | 10,602 | 186 | 51,500 | 36,853 | 2,069 | 12,348 | 230 |
| 1974 | 41,853 | 30,167 | 1,578 | 9,896 | 212 | 50,641 | 36,119 | 1,715 | 12,552 | 255 |
| 1975 | 42,226 | 30,338 | 1,500 | 10,232 | 156 | 46,715 | 33,429 | 1,888 | 11,184 | 214 |
| 1976 | 41,611 | 29,128 | 1,347 | 10,941 | 195 | 44,280 | 32,174 | 1,813 | 10,083 | 210 |
| 1977 | 40,801 | 28,500 | 1,178 | 10,898 | 225 | 41,485 | 29,566 | 1,484 | 10,249 | 186 |
| 1978 | 39,590 | 27,704 | 1,201 | 10,456 | 229 | 41,254 | 29,421 | 1,233 | 10,399 | 201 |
| 1979 | 38,901 | 27,285 | 1,086 | 10,269 | 261 | 30,079 | 21,145 | 961 | 7,804 | 169 |
| 1980 | 38,688 | 27,484 | 1,133 | 9,798 | 273 | 37,356 | 25,967 | 1,232 | 9,940 | 217 |
| 1981 | 36,169 | 26,360 | 1,146 | 8,414 | 249 | 39,223 | 27,623 | 1,117 | 10,241 | 242 |
| 1982[3] | 36,700 | 26,700 | 1,200 | 8,500 | 300 | 33,896 | 24,085 | 1,003 | 8,539 | 269 |
| 1983[3] | 34,400 | 25,100 | 1,100 | 8,000 | 200 | 32,871 | 24,038 | 1,043 | 7,562 | 228 |
| 1984[3] | 35,800 | 26,100 | 1,100 | 8,300 | 200 | 38,365 | 28,002 | 1,228 | 8,887 | 248 |
| 1985[3] | 37,000 | 27,000 | 1,200 | 8,600 | 300 | 39,554 | 28,944 | 1,124 | 9,243 | 243 |
| 1986[3] | 39,000 | 28,400 | 1,200 | 9,100 | 300 | 38,124 | 27,324 | 1,011 | 9,461 | 328 |

[1] Includes unassigned patents.

[2] Comprises patents assigned to foreign corporations, governments, and individuals

[3] Data by date of application are estimated.

Note: NA – Not available.

SOURCES: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office (OTAF). *Special Report A Profile of U S Patent Activity, 1978;* OTAF *Indicators of Patent Output of U.S. Industry (1963-79)*, June 1980. OTAF *Indicators of Patent Output of U.S. Industry (1963-81)*, June 1982, and OTAF unpublished data

See figure 6-6.

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## Appendix table 6-10. Shares of U.S. patents granted to inventors in various countries, by product field: 1975 and 1986

| Product fields | Patents granted to all countries | United States | Japan | West Germany | United Kingdom | France | Canada | Italy | Other countries |
|---|---|---|---|---|---|---|---|---|---|
| | **1975** | | | | | | | | |
| | | Percent | | | | | | | |
| All technologies[1] | 72,000 | 64.9 | 8.8 | 8.4 | 4.2 | 3.3 | 1.8 | 1.0 | 7.6 |
| Food and kindred products | 701 | 70.3 | 7.7 | 4.1 | 5.7 | 1.7 | 0.4 | 0.3 | 9.7 |
| Textile mill products | 475 | 61.7 | 9.9 | 11.8 | 6.1 | 3.2 | 0.8 | 0.4 | 6.1 |
| Chemicals, except drugs & medicines | 10,806 | 58.5 | 9.8 | 11.8 | 4.6 | 3.7 | 1.1 | 1.6 | 8.9 |
| Drugs & medicines | 1,067 | 54.8 | 12.4 | 10.0 | 4.7 | 6.4 | 1.8 | 1.8 | 8.2 |
| Petroleum & natural gas extraction & refining | 754 | 86.3 | 2.5 | 1.7 | 2.8 | 2.1 | 2.0 | 0.1 | 2.4 |
| Rubber & miscellaneous plastic products | 2,931 | 65.7 | 10.1 | 7.8 | 4.6 | 3.3 | 1.8 | 1.2 | 5.5 |
| Stone, clay, glass, & concrete products | 1,375 | 65.0 | 8.0 | 6.8 | 7.1 | 3.1 | 1.4 | 0.8 | 7.9 |
| Primary metals | 855 | 53.1 | 13.1 | 7.6 | 4.5 | 3.1 | 3.6 | 0.9 | 14.1 |
| Fabricated metal products | 6,064 | 71.4 | 5.4 | 6.7 | 3.9 | 2.7 | 2.1 | 0.9 | 6.9 |
| Machinery, except electrical (excl. Off., computing & accounting machines) | 15,748 | 62.6 | 6.7 | 9.7 | 4.3 | 3.5 | 2.3 | 1.2 | 9.7 |
| Office, computing, & accounting machines | 1,465 | 64.8 | 12.8 | 7.8 | 3.5 | 2.9 | 1.0 | 1.2 | 5.9 |
| Electrical & electronic machinery, except communication equipment | 4,325 | 64.3 | 9.6 | 9.8 | 4.1 | 3.1 | 1.4 | 1.1 | 6.5 |
| Communication equipment & electronic components | 7,106 | 66.7 | 12.7 | 6.0 | 4.2 | 3.3 | 1.3 | 0.6 | 5.2 |
| Motor vehicles and other transportation equipment, except aircraft | 3,163 | 65.8 | 7.1 | 9.9 | 4.9 | 4.6 | 1.9 | 0.9 | 5.0 |
| Aircraft & parts | 705 | 60.7 | 9.6 | 10.2 | 7.4 | 5.5 | 1.8 | 0.6 | 4.1 |
| Professional & scientific instruments | 8,457 | 65.9 | 11.9 | 7.0 | 3.4 | 2.4 | 1.4 | 0.7 | 7.3 |
| | **1986** | | | | | | | | |
| | | Percent | | | | | | | |
| All technologies[1] | 70,860 | 53.8 | 18.6 | 9.6 | 3.4 | 3.3 | 1.9 | 1.4 | 8.0 |
| Food and kindred products | 454 | 62.6 | 11.2 | 6.4 | 2.9 | 3.1 | 3.1 | 1.1 | 9.7 |
| Textile mill products | 461 | 52.1 | 16.9 | 12.6 | 3.7 | 3.0 | 1.3 | 0.7 | 9.8 |
| Chemicals, except drugs & medicines | 7,804 | 53.8 | 15.2 | 12.6 | 3.9 | 3.8 | 1.2 | 1.8 | 7.7 |
| Drugs & medicines | 1,411 | 48.6 | 16.2 | 10.8 | 6.1 | 4.7 | 3.5 | 2.6 | 7.6 |
| Petroleum & natural gas extraction & refining | 789 | 80.5 | 6.3 | 2.9 | 1.3 | 2.2 | 2.3 | 0.4 | 4.2 |
| Rubber & miscellaneous plastic products | 2,856 | 56.2 | 18.0 | 10.5 | 3.3 | 2.7 | 1.7 | 1.2 | 6.5 |
| Stone, clay, glass & concrete products | 1,352 | 53.1 | 19.5 | 9.9 | 3.7 | 3.3 | 1.7 | 1.1 | 7.7 |
| Primary metals | 720 | 43.1 | 22.8 | 9.4 | 4.4 | 3.1 | 3.9 | 1.0 | 12.4 |
| Fabricated metal products | 5,739 | 58.9 | 11.9 | 9.6 | 3.3 | 3.4 | 2.7 | 0.9 | 9.2 |
| Machinery, except electrical (excl. Off., computing & accounting machines) | 13,766 | 50.2 | 15.3 | 13.5 | 3.3 | 3.4 | 2.1 | 2.0 | 10.2 |
| Office, computing, & accounting machines | 2,462 | 46.5 | 32.6 | 5.9 | 2.0 | 1.7 | 0.9 | 1.5 | 8.9 |
| Electrical & electronic machinery, except communication equipment | 4,392 | 52.5 | 21.1 | 9.3 | 3.4 | 3.5 | 1.4 | 1.6 | 7.2 |
| Communication equipment & electronic components | 8,822 | 54.2 | 25.5 | 5.5 | 3.5 | 3.8 | 1.5 | 0.7 | 5.3 |
| Motor vehicles and other transportation equipment, except aircraft | 2,809 | 46.5 | 23.1 | 12.8 | 3.2 | 3.7 | 1.8 | 1.9 | 7.0 |
| Aircraft & parts | 816 | 40.1 | 30.4 | 12.5 | 4.4 | 5.0 | 1.1 | 1.2 | 5.3 |
| Professional & scientific instruments | 10,048 | 53.2 | 23.1 | 7.7 | 3.7 | 2.9 | 1.6 | 0.9 | 6.9 |

[1] The total number of patents reported under "All technologies" is somewhat greater than the sum of the patents allocated to different product groups, because some patents are not allocated to product groups.

SOURCE: U.S. Department of Commerce, U.S. Patent and Trademark Office, *Patenting Trends in the United States, 1963-1986* (June, 1987), and unpublished data

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## Appendix table 6-11. U.S. patents granted to inventors in various countries, for selected technologies: 1975, 1986

| Technology group | Total | | United States | | Japan | | West Germany | | France | | United Kingdom | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975 | 1986 | 1975 | 1986 | 1975 | 1986 | 1975 | 1986 | 1975 | 1986 | 1975 | 1986 | 1975 | 1986 |
| | Patents granted | | | | | | | | | | | | | |
| All technologies | 72,000 | 70,860 | 46,715 | 38,124 | 6,352 | 13,209 | 6,036 | 6,803 | 2,367 | 2,369 | 3,043 | 2,409 | 7,487 | 7,946 |
| Solar energy | 148 | 432 | 116 | 288 | 6 | 84 | 10 | 18 | 9 | 4 | 3 | 3 | 4 | 35 |
| Jet engines | 658 | 422 | 437 | 252 | 26 | 37 | 57 | 38 | 31 | 20 | 50 | 23 | 57 | 52 |
| Light wave communications | 307 | 497 | 209 | 257 | 47 | 118 | 15 | 40 | 10 | 30 | 19 | 26 | 7 | 26 |
| Light wave & multiplexed light wave communications per se | 42 | 103 | 31 | 58 | 7 | 18 | 1 | 10 | 2 | 6 | 1 | 6 | 0 | 5 |
| Machine tools - metal working | 1,121 | 1,178 | 724 | 598 | 87 | 200 | 116 | 162 | 27 | 24 | 39 | 37 | 128 | 157 |
| Telecommunications | 2,532 | 3,904 | 1,665 | 2,043 | 346 | 1,028 | 133 | 207 | 91 | 161 | 120 | 167 | 177 | 298 |
| Internal combustion engines | 1,019 | 1,213 | 547 | 342 | 170 | 532 | 138 | 170 | 41 | 33 | 53 | 49 | 70 | 87 |
| Steel and iron | 593 | 469 | 287 | 173 | 104 | 137 | 54 | 50 | 17 | 19 | 12 | 14 | 119 | 76 |
| Laser light sources and detectors | 79 | 113 | 50 | 57 | 11 | 40 | 5 | 7 | 4 | 3 | 7 | 3 | 2 | 3 |
| Nuclear energy | 409 | 528 | 288 | 296 | 13 | 58 | 32 | 52 | 22 | 62 | 19 | 17 | 35 | 43 |
| Semiconductor devices & manufacture | 1,082 | 1,586 | 739 | 908 | 141 | 458 | 87 | 81 | 24 | 41 | 38 | 35 | 53 | 63 |
| Light transmitting fiber, waveguide or rod | 201 | 310 | 140 | 160 | 31 | 64 | 9 | 25 | 4 | 25 | 12 | 17 | 5 | 19 |
| General purpose programmable digital computer systems | 146 | 353 | 113 | 243 | 7 | 68 | 8 | 12 | 2 | 9 | 8 | 7 | 8 | 14 |
| Robots | 49 | 214 | 31 | 106 | 10 | 63 | 0 | 16 | 1 | 10 | 0 | 8 | 7 | 11 |
| Genetic engineering | 11 | 116 | 3 | 91 | 3 | 13 | 1 | 4 | 0 | 0 | 0 | 4 | 4 | 4 |
| | National shares (percent) | | | | | | | | | | | | | |
| All technologies | | | 64.88 | 53.80 | 8.82 | 18.64 | 8.38 | 9.60 | 3.29 | 3.34 | 4.23 | 3.40 | 10.40 | 11.21 |
| Solar energy | | | 78.38 | 66.67 | 4.05 | 19.44 | 6.76 | 4.17 | 6.08 | 0.93 | 2.03 | 0.69 | 2.70 | 8.10 |
| Jet engines | | | 66.41 | 59.72 | 3.95 | 8.77 | 8.66 | 9.00 | 4.71 | 4.74 | 7.60 | 5.45 | 8.66 | 12.32 |
| Light wave communications | | | 68.08 | 51.71 | 15.31 | 23.74 | 4.89 | 8.05 | 3.26 | 6.04 | 6.19 | 5.23 | 2.28 | 5.23 |
| Light wave & multiplexed light wave communications per se | | | 73.81 | 56.31 | 16.67 | 17.48 | 2.38 | 9.71 | 4.76 | 5.83 | 2.38 | 5.83 | 0.00 | 4.85 |
| Machine tools - metal working | | | 64.59 | 50.76 | 7.76 | 16.98 | 10.35 | 13.75 | 2.41 | 2.04 | 3.48 | 3.14 | 11.42 | 13.33 |
| Telecommunications | | | 65.76 | 52.33 | 13.67 | 26.33 | 5.25 | 5.30 | 3.59 | 4.12 | 4.74 | 4.28 | 6.99 | 7.63 |
| Internal combustion engines | | | 53.68 | 28.19 | 16.68 | 43.86 | 13.54 | 14.01 | 4.02 | 2.72 | 5.20 | 4.04 | 6.87 | 7.17 |
| Steel and iron | | | 48.40 | 36.89 | 17.54 | 29.21 | 9.11 | 10.66 | 2.87 | 4.05 | 2.02 | 2.99 | 20.07 | 16.20 |
| Laser light sources and detectors | | | 63.29 | 50.44 | 13.92 | 35.40 | 6.33 | 6.19 | 5.06 | 2.65 | 8.86 | 2.65 | 2.53 | 2.65 |
| Nuclear energy | | | 70.42 | 56.06 | 3.18 | 10.98 | 7.82 | 9.85 | 5.38 | 11.74 | 4.65 | 3.22 | 8.56 | 8.14 |
| Semiconductor devices & manufacture | | | 68.30 | 57.25 | 13.03 | 28.88 | 8.04 | 5.11 | 2.22 | 2.59 | 3.51 | 2.21 | 4.90 | 3.97 |
| Light transmitting fiber, waveguide or rod | | | 69.65 | 51.61 | 15.42 | 20.65 | 4.48 | 8.06 | 1.99 | 8.06 | 5.97 | 5.48 | 2.49 | 6.13 |
| General purpose programmable digital computer systems | | | 77.40 | 68.84 | 4.79 | 19.26 | 5.48 | 3.40 | 1.37 | 2.55 | 5.48 | 1.98 | 5.48 | 3.97 |
| Robots | | | 63.27 | 49.53 | 20.41 | 29.44 | 0.00 | 7.48 | 2.04 | 4.67 | 0.00 | 3.74 | 14.29 | 5.14 |
| Genetic engineering | | | 27.27 | 78.45 | 27.27 | 11.21 | 9.09 | 3.45 | 0.00 | 0.00 | 0.00 | 3.45 | 36.36 | 3.45 |

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, unpublished data

## Appendix table 6-12. Success rates of patent applications to U.S. Patent and Trademark Office, by applying country: 1975, 1981

| Year of application | United States | Japan | Netherlands | United Kingdom | West Germany | Canada | Sweden | France | Switzerland | Italy |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | | | | |
| 1975 .............. | 65.5 | 70.9 | 65.3 | 58.4 | 66.1 | 53.2 | 65.7 | 70.6 | 65.2 | 60.5 |
| 1981 .............. | 58.0 | 70.8 | 61.0 | 50.4 | 60.4 | 51.9 | 56.9 | 63.4 | 61.2 | 51.2 |

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, unpublished data

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## Appendix table 6-13. U.S. employment, by size of firm, 1975-84

| | Firm size (number of employees) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Less than 20 | 20-99 | 100-499 | Total small business | 500-999 | Greater than 1000 | Total large business | Total employment |
| | Thousands | | | | | | | |
| 1975 .............. | 16,393 | 16,272 | 13,713 | 46,378 | 4,872 | 9,315 | 14,187 | 60,565 |
| 1976 .............. | 16,821 | 17,099 | 14,434 | 48,354 | 5,053 | 9,241 | 14,294 | 62,648 |
| 1977 .............. | 17,605 | 17,815 | 14,956 | 50,376 | 5,157 | 9,443 | 14,600 | 64,976 |
| 1978 .............. | 18,723 | 19,612 | 16,327 | 54,662 | 5,537 | 10,090 | 15,627 | 70,289 |
| 1979 .............. | 19,406 | 20,992 | 17,527 | 57,925 | 5,780 | 10,976 | 16,756 | 74,681 |
| 1980 .............. | 19,423 | 21,168 | 17,840 | 58,431 | 5,689 | 10,716 | 16,405 | 74,836 |
| 1981 .............. | 19,515 | 21,231 | 17,977 | 58,723 | 5,497 | 10,630 | 16,127 | 74,850 |
| 1982 .............. | 19,898 | 21,143 | 17,444 | 58,485 | 5,436 | 10,376 | 15,812 | 74,297 |
| 1983 .............. | 20,136 | 20,806 | 16,794 | 57,736 | 5,186 | 10,050 | 15,236 | 72,972 |
| 1984 .............. | 21,171 | 22,449 | 18,348 | 61,968 | 5,614 | 10,413 | 16,027 | 77,995 |
| | Average annual growth Percent | | | | | | | |
| 1975-80 ........... | 3.45 | 5.40 | 5.40 | 4.73 | 3.15 | 2.84 | 0.03 | 4.32 |
| 1980-84 ........... | 2.18 | 1.48 | 0.70 | 1.48 | −0.33 | −0.71 | −0.58 | 1.04 |
| 1975-84 ........... | 2.88 | 3.64 | 3.29 | 3.27 | 1.59 | 1.25 | 1.36 | 2.85 |

SOURCE: U.S. Bureau of the Census, *Statistical Abstract of the United States, 1987*, Washington, DC (1986), p. 507

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## Appendix table 6-14. Venture capital[1] resources, commitments and disbursements: 1978-86

| Year | Net new private capital committed to venture capital firms[2] | Total pool of capital under management | Disbursements excluding SBIC straight debt lending[3] and leveraged buyout financing |
|---|---|---|---|
| | Millions of dollars | | |
| 1978 .............. | 600 | 3,500 | 332 |
| 1979 .............. | 300 | 3,800 | 665 |
| 1980 ....... . .... | 700 | 4,500 | 799 |
| 1981 .............. | 1,300 | 5,800 | 1,171 |
| 1982 .............. | 1,800 | 7,600 | 1,566 |
| 1983 .............. | 4,500 | 12,100 | 2,457 |
| 1984 .............. | 4,200 | 16,300 | 2,651 |
| 1985 .............. | 3,300 | 19,600 | 2,272 |
| 1986 .............. | 4,500 | 24,100 | 2,392 |

[1] Data describe resources of venture capital firms reporting to Venture Economics, Inc. In 1984-85, the Venture Economics database covered about 600 U.S. venture capital firms.

[2] Total new private capital less capital withdrawals.

[3] Debt financing by licensed Small Business Investment Corporations

SOURCE: Venture Economics, Inc., special tabulations prepared for the National Science Foundation

See figure 6-8.

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## Appendix table 6-15. Venture capital investments, by industry: 1984-86

| Industry | Early stage investment[1] | | | Later stage investment[2] | | |
|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1984 | 1985 | 1986 |
| | Millions of dollars | | | | | |
| Total | 1,027.6 | 684.4 | 928.3 | 1.389.8 | 1.344.7 | 1.292.5 |
| Commercial communications. telephone & data communications | 159.0 | 110.6 | 127.7 | 217.0 | 208.3 | 242.8 |
| Computers & computer related | 387.3 | 224.0 | 254.3 | 680.4 | 530.7 | 428.8 |
| Electronic components & other electronics | 174.9 | 110.1 | 141.1 | 151.1 | 214.7 | 169.2 |
| Biotechnology | 20.2 | 18.8 | 40.2 | 42.6 | 54.9 | 76.8 |
| Other medical/health | 132.3 | 102.1 | 177.1 | 108.5 | 119.2 | 122.8 |
| Chemicals & materials | 14.1 | 14.5 | 9.6 | 5.9 | 5.3 | 1.2 |
| Industrial automation | 31.4 | 23.0 | 12.2 | 42.7 | 58.9 | 35.0 |
| Industrial equipment & machinery | 6.4 | 0.9 | 6.1 | 21.5 | 23.1 | 14.4 |
| Energy | 4.6 | 6.8 | 0.3 | 20.4 | 15.9 | 14.1 |
| Consumer | 34.7 | 30.5 | 82.2 | 67.0 | 78.1 | 116.5 |
| Other | 62.7 | 43.1 | 77.5 | 32.7 | 35.6 | 70.9 |
| | Distribution by industry Percent | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Commercial communications. telephone & data communications | 15.5 | 16.2 | 13.8 | 15.6 | 15.5 | 18.8 |
| Computers & computer related | 37.7 | 32.7 | 27.4 | 49.0 | 39.5 | 33.2 |
| Electronic components & other electronics | 17.0 | 16.1 | 15.2 | 10.9 | 16.0 | 13.1 |
| Biotechnology | 2.0 | 2.7 | 4.3 | 3.1 | 4.1 | 5.9 |
| Other medical/health | 12.9 | 14.9 | 19.1 | 7.8 | 8.9 | 9.5 |
| Chemicals & materials | 1.4 | 2.1 | 1.0 | 0.4 | 0.4 | 0.1 |
| Industrial automation | 3.1 | 3.4 | 1.3 | 3.1 | 4.4 | 2.7 |
| Industrial equipment & machinery | 0.6 | 0.1 | 0.7 | 1.5 | 1.7 | 1.1 |
| Energy | 0.4 | 1.0 | 0.0 | 1.5 | 1.2 | 1.1 |
| Consumer | 3.4 | 4.5 | 8.9 | 4.8 | 5.8 | 9.0 |
| Other | 6.1 | 6.3 | 8.3 | 2.4 | 2.6 | 5.5 |

[1] Early-stage investment includes capital to develop prototypes. begin production. and initiate marketing Research and development partnerships to launch new businesses are included.

[2] Later-stage investment provides capital for the expansion of firms which are already producing and marketing products. It includes bridge financing for firms which are going public. as well as research and development partnerships which fund new product development by established firms.

SOURCE: Venture Economics. Inc.. special tabulations prepared for the National Science Foundation

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**Appendix table 6-16. Venture-backed initial public offerings by small firms: 1984-86**

| Industry | 1984 | 1985 | 1986 |
|---|---|---|---|
| | Millions of dollars | | |
| Total | 477.6 | 344.9 | 1443.8 |
| Commercial communications, telephone & data communications | 46.5 | 66.2 | 66.3 |
| Computers & computer related | 257.9 | 131.7 | 376.1 |
| Electronic components & other electronics | 61.6 | 0.0 | 117.1 |
| Biotechnology | 12.7 | 0.0 | 269.5 |
| Other medical/health | 15.0 | 27.9 | 136.4 |
| Industrial automation | 9.6 | 15.2 | 0.0 |
| Industrial equipment & machinery | 8.0 | 34.2 | 23.5 |
| Consumer | 60.3 | 54.4 | 185.5 |
| Other | 6.0 | 15.3 | 269.5 |
| | Distribution by industry Percent | | |
| Total | 100.0 | 100.0 | 100.0 |
| Commercial communications, telephone & data communications | 9.7 | 19.2 | 4.6 |
| Computers & computer related | 54.0 | 38.2 | 26.0 |
| Electronic components & other electronics | 12.9 | 0.0 | 8.1 |
| Biotechnology | 2.6 | 0.0 | 18.7 |
| Other medical/health | 3.1 | 8.1 | 9.4 |
| Industrial automation | 2.0 | 4.4 | 0.0 |
| Industrial equipment & machinery | 1.7 | 9.9 | 1.6 |
| Consumer | 12.6 | 15.8 | 12.8 |
| Other | 1.3 | 4.4 | 18.7 |

SOURCE: Venture Economics, Inc., special tabulations prepared for the National Science Foundation

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## Appendix table 6-17. Number of small[1] firms active in selected biotechnology product groups in 1986

| All biotechnology | Animal biotechnology | Cell cultures | Catalysts | Bioelectronics | Biotechnology equipment | Enzymes | Genetic engineering | Immunology | Biomass/ biochemicals | Biomaterials | Proteins | Plant biotechnology | Bioprocessing | Biological testing | Other biotechnology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Number of firms | | | | | | | | |
| 252 | 28 | 41 | 9 | 2 | 67 | 22 | 68 | 31 | 32 | 5 | 9 | 16 | 7 | 2 | 1 |
| 28 | 28 | 4 | 0 | 0 | 3 | 1 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 4 | 41 | 2 | 0 | 6 | 2 | 3 | 3 | 4 | 0 | 2 | 2 | 1 | 0 | 0 |
| 9 | 0 | 2 | 9 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 67 | 3 | 6 | 0 | 0 | 67 | 4 | 8 | 1 | 3 | 1 | 1 | 0 | 2 | 0 | 0 |
| 22 | 1 | 2 | 4 | 0 | 4 | 22 | 7 | 3 | 4 | 0 | 3 | 0 | 2 | 0 | 0 |
| 68 | 6 | 3 | 0 | 0 | 8 | 7 | 68 | 11 | 3 | 0 | 3 | 1 | 1 | 0 | 1 |
| 31 | 4 | 3 | 0 | 0 | 1 | 3 | 11 | 31 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 32 | 0 | 4 | 1 | 0 | 3 | 4 | 3 | 1 | 32 | 2 | 2 | 1 | 2 | 1 | 0 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 2 | 1 | 0 | 1 | 3 | 3 | 3 | 2 | 0 | 9 | 0 | 1 | 0 | 0 |
| 16 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 16 | 0 | 0 | 0 |
| 7 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 0 | 2 | 0 | 1 | 0 | 7 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Note: The table shows the number of firms active in each product group, broken down by the other product groups in which the firms are active. It is thus a symmetric matrix, with the diagonal representing the total number of firms in each product group.

[1] Firms with less than 1,000 employees

SOURCE: Derived from the CorpTech data base. Corporate Technology Information Services, Inc., Wellesley Hills, MA

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## Appendix table 6-18. Small[1] firms active in selected biotechnology product groups in 1986, by type of ownership

| Product groups | Total | Publicly held | Privately held |
|---|---|---|---|
| | Number of firms | | |
| All biotechnology | 252 | 58 | 194 |
| Animal biotechnology | 28 | 5 | 23 |
| Cell cultures | 41 | 8 | 33 |
| Catalysts | 9 | 2 | 7 |
| Bioelectronics | 2 | 0 | 2 |
| Biotechnology equipment | 67 | 14 | 53 |
| Enzymes | 22 | 5 | 17 |
| Genetic engineering | 68 | 20 | 48 |
| Immunology | 31 | 12 | 19 |
| Biomass/biochemicals | 32 | 8 | 24 |
| Biomaterials | 5 | 0 | 5 |
| Proteins | 9 | 1 | 8 |
| Plant biotechnology | 16 | 4 | 12 |
| Bioprocessing | 7 | 1 | 6 |
| Biological testing | 2 | 1 | [illegible] |
| Other biotechnology | 1 | 1 | 0 |
| | Percent | | |
| All biotechnology | 100.0 | 23.0 | 77.0 |
| Animal biotechnology | 100.0 | 17.9 | 82.1 |
| Cell cultures | 100.0 | 19.5 | 80.5 |
| Catalysts | 100.0 | 22.2 | 77.8 |
| Bioelectronics | 100.0 | 0.0 | 100.0 |
| Biotechnology equipment | 100.0 | 20.9 | 79.1 |
| Enzymes | 100.0 | 22.7 | 77.3 |
| Genetic engineering | 100.0 | 29.4 | 70.6 |
| Immunology | 100.0 | 38.7 | 61.3 |
| Biomass/biochemicals | 100.0 | 25.0 | 75.0 |
| Biomaterials | 100.0 | 0.0 | 100.0 |
| Proteins | 100.0 | 11.1 | 88.9 |
| Plant biotechnology | 100.0 | 25.0 | 75.0 |
| Bioprocessing | 100.0 | 14.3 | 85.7 |
| Biological testing | 100.0 | 50.0 | 50.0 |
| Other biotechnology | 100.0 | 100.0 | 0.0 |

[1] Firms with fewer than 1,000 employees

Note: Because many firms reported activity in more than one field, the sum of the individual fields is greater than the total number of firms reporting biotechnology activity

SOURCE: Derived from the CorpTech data base. Corporate Technology Information Services, Inc. Wellesley Hills, MA

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## Appendix table 6-19. Number of small[1] firms active in biotechnology fields, by year of formation

| Biotechnology fields | Pre-1965 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of firms | | | | | | | | | | | | | | | | | | | | | |
| All biotechnology | 32 | 1 | 1 | 3 | 3 | 4 | 3 | 6 | 11 | 8 | 7 | 5 | 11 | 5 | 10 | 18 | 13 | 40 | 25 | 29 | 10 | 7 |
| Animal biotechnology | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 | 1 | 0 | 1 | 3 | 3 | 1 | 1 | 7 | 2 | 1 |
| Cell cultures | 7 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 4 | 2 | 0 | 1 | 4 | 2 | 5 | 2 | 5 | 1 | 0 |
| Catalysts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 2 | 1 | 0 |
| Bioelectronics | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Biotechnology equipment | 9 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 0 | 5 | 2 | 1 | 7 | 1 | 3 | 3 | 3 | 3 | 6 | 7 | 4 | 1 |
| Enzymes | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 1 | 2 | 5 | 2 | 3 | 1 | 0 |
| Genetic engineering | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 6 | 1 | 4 | 3 | 3 | 16 | 13 | 9 | 1 | 5 |
| Immunology | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 3 | 2 | 10 | 1 | 5 | 0 | 0 |
| Biomass/biochemicals | 6 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 5 | 0 | 2 | 5 | 4 | 3 | 0 | 0 |
| Biomaterials | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 |
| Proteins | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| Plant biotechnology | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 4 | 2 | 1 | 0 | 0 |
| Bioprocessing | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Biological testing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Other biotechnology | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[1] Firms with less than 1,000 employees

Note. The table shows the number of firms active in each biotechnology field in 1986, broken down by the year in which they were formed. Because many firms reported activity in more than one field, the sum of the individual fields is generally greater than the total number of firms reporting biotechnology activity

SOURCE: Derived from the CorpTech data base, Corporate Technology Information Services, Inc., Wellesley Hills, MA

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## Appendix table 6-20. New products first marketed in 1985, by size of firm

| Firm size, millions of dollars in net sales | Number of products per: | |
|---|---|---|
| | Millions of dollars of net sales | Millions of dollars of R&D |
| All firms .......... | 0.0076 | 0.254 |
| Less than 100 ... | 0.0892 | 2.152 |
| 100-350 ........ | 0.0348 | 1.531 |
| 350-1,000 ...... | 0.0186 | 0.564 |
| 1,000-4,000 ..... | 0.0072 | 0.239 |
| 4,000 and more . | 0.0011 | 0.037 |

Note: Data based on sample of 620 firms

SOURCE: National Science Foundation, Division of Science Resources Studies, Economic Analysis Studies Group, unpublished data

See figure O-30 in Overview.

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## Appendix table 7-1. U.S. trade in high-technology[1] and other manufacturing product groups: 1970-86

| | High technology | | | Non-high technology | | | U.S. manufactures | | |
|---|---|---|---|---|---|---|---|---|---|
| | Exports | Imports | Balance | Exports | Imports | Balance | Exports | Imports | Balance |
| | | | | Billions of constant 1982[2] dollars | | | | | |
| 1970[1] | 24.5 | 10.0 | 14.5 | 45.2 | 54.2 | 9.0 | 69.7 | 64.2 | 5.5 |
| 1971[1] | 25.7 | 11.0 | 14.6 | 42.8 | 61.7 | 18.9 | 68.5 | 72.8 | -4.3 |
| 1972[1] | 25.6 | 13.6 | 12.0 | 46.9 | 72.5 | 25.6 | 72.5 | 86.0 | -13.6 |
| 1973[3] | 32.1 | 15.9 | 16.1 | 58.1 | 80.3 | 22.2 | 90.2 | 96.3 | 6.1 |
| 1974 | 39.8 | 18.2 | 21.7 | 77.8 | 92.1 | 14.3 | 117.7 | 110.3 | 7.4 |
| 1975 | 38.6 | 16.0 | 22.6 | 81.1 | 76.7 | 4.4 | 119.7 | 92.7 | 27.0 |
| 1976 | 40.6 | 20.9 | 19.7 | 81.8 | 89.4 | 7.6 | 122.4 | 110.4 | 12.1 |
| 1977 | 40.6 | 22.7 | 17.8 | 78.6 | 99.0 | 20.4 | 119.2 | 121.7 | 2.5 |
| 1978 | 48.2 | 28.1 | 20.1 | 82.6 | 119.8 | 37.2 | 130.9 | 147.9 | 17.0 |
| 1979 | 55.4 | 29.0 | 26.4 | 93.0 | 122.2 | 29.2 | 148.4 | 151.2 | 2.8 |
| 1980 | 63.8 | 32.7 | 31.1 | 117.9 | 129.2 | 11.3 | 181.8 | 161.9 | 19.9 |
| 1981 | 64.3 | 36.0 | 28.3 | 113.3 | 130.4 | 17.1 | 177.6 | 166.4 | 11.2 |
| 1982 | 58.1 | 34.5 | 23.6 | 93.2 | 123.6 | 30.4 | 151.3 | 158.1 | 6.8 |
| 1983 | 57.9 | 39.9 | 18.1 | 80.2 | 132.0 | 51.7 | 138.2 | 171.8 | -33.7 |
| 1984 | 60.7 | 55.1 | 5.6 | 86.2 | 169.0 | 82.9 | 146.9 | 224.1 | -77.3 |
| 1985 | 61.4 | 58.1 | 3.3 | 83.9 | 183.5 | 99.6 | 145.2 | 241.5 | 96.3 |
| 1986 | 63.3 | 65.5 | 2.3 | 84.9 | 204.0 | 119.1 | 148.2 | 269.5 | 121.4 |
| | | | | Billions of dollars | | | | | |
| 1970[1] | 10.3 | 4.2 | 6.1 | 19.0 | 22.8 | 3.8 | 29.3 | 27.0 | 2.3 |
| 1971[1] | 11.4 | 4.9 | 6.5 | 19.0 | 27.4 | 8.4 | 30.4 | 32.3 | 1.9 |
| 1972[3] | 11.9 | 6.3 | 5.6 | 21.8 | 33.7 | 11.9 | 33.7 | 40.0 | 6.3 |
| 1973[3] | 15.9 | 7.9 | 8.0 | 28.8 | 39.8 | 11.0 | 44.7 | 47.7 | 3.0 |
| 1974 | 21.5 | 9.8 | 11.7 | 42.0 | 49.7 | 7.7 | 63.5 | 59.5 | 4.0 |
| 1975 | 22.9 | 9.5 | 13.4 | 48.1 | 45.5 | 2.6 | 71.0 | 55.0 | 16.0 |
| 1976 | 25.6 | 13.2 | 12.4 | 51.6 | 56.4 | 4.8 | 77.2 | 69.6 | 7.6 |
| 1977 | 27.3 | 15.3 | 12.0 | 52.9 | 66.6 | 13.7 | 80.2 | 81.9 | 1.7 |
| 1978 | 34.8 | 20.3 | 14.5 | 59.7 | 86.5 | 26.8 | 94.5 | 106.8 | 12.3 |
| 1979 | 43.5 | 22.8 | 20.8 | 73.1 | 96.0 | 23.0 | 116.6 | 118.8 | 2.2 |
| 1980 | 54.7 | 28.0 | 26.7 | 101.1 | 110.8 | 9.7 | 155.8 | 138.8 | 17.0 |
| 1981 | 60.4 | 33.8 | 26.6 | 106.5 | 122.5 | 16.1 | 166.8 | 156.4 | 10.5 |
| 1982 | 58.1 | 34.5 | 23.6 | 93.2 | 123.6 | 30.4 | 151.3 | 158.1 | 6.8 |
| 1983 | 60.2 | 41.4 | 18.8 | 83.3 | 137.1 | 53.7 | 143.5 | 178.5 | 35.0 |
| 1984 | 65.5 | 59.5 | 6.0 | 92.9 | 182.3 | 89.4 | 158.4 | 241.8 | 83.3 |
| 1985 | 68.4 | 64.8 | 3.6 | 93.5 | 204.6 | 111.0 | 162.0 | 269.4 | 107.4 |
| 1986 | 72.5 | 75.1 | 2.6 | 97.3 | 233.8 | 136.5 | 169.8 | 308.9 | 139.1 |

[1] U.S. Department of Commerce DOC-3 definitions

[2] Converted to constant dollars using the GNP implicit price deflator

[3] Estimated

SOURCE: U.S. Department of Commerce, International Trade Administration, *U.S. Trade Performance in 1985 and Outlook* (October 1986), and U.S. Department of Commerce, unpublished data

See figure O-26 in Overview

Appendix table 7-2. U.S. exports as a percentage of shipments, high-technology and other manufactured products: 1978-1985

| Product groups | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|
| | Exports as a percent of shipments | | | | | | | |
| | Percent | | | | | | | |
| All manufactured products | 6.2 | 6.8 | 8.4 | 8.3 | 7.9 | 7.0 | 7.0 | 6.9 |
| All high-technology products | 18.1 | 19.7 | 20.5 | 20.4 | 18.7 | 16.5 | 17.2 | 17.3 |
| Guided missiles and spacecraft | 8.4 | 6.9 | 7.5 | 4.7 | 8.5 | 6.6 | 5.5 | 4.7 |
| Communications equipment & electronic components | 14.0 | 17.8 | 15.3 | 15.1 | 14.2 | 11.4 | 15.9 | 12.0 |
| Aircraft and parts | 35.3 | 31.6 | 33.6 | 35.8 | 30.3 | 24.2 | 25.6 | 27.9 |
| Office and computing machines | 25.1 | 25.7 | 28.3 | 27.7 | 25.2 | 21.3 | 32.1 | 27.6 |
| Ordnance and accessories | 21.5 | 23.9 | 20.7 | 18.9 | 18.0 | 22.7 | 19.5 | 15.0 |
| Drugs and medicine | 12.2 | 10.4 | 11.2 | 11.2 | 10.2 | 10.2 | 9.9 | 9.2 |
| Industrial inorganic chemicals | 16.0 | 18.1 | 18.6 | 19.1 | 18.3 | 9.1 | 20.8 | 20.0 |
| Professional and scientific instruments | 16.3 | 17.6 | 18.1 | 17.9 | 16.5 | 15.8 | 15.3 | 14.8 |
| Engines, turbines, and parts | 19.9 | 22.9 | 27.4 | 26.1 | 28.5 | 20.3 | 26.0 | 21.4 |
| Plastic materials, synthetics | 9.7 | 13.8 | 16.2 | 14.6 | | 11.9 | [illegible]2 | 12.5 |
| Other manufacturing products | 4.5 | 4.8 | 6.4 | 6.2 | | 5.0 | 4.9 | 4.8 |
| | Exports | | | | | | | |
| | Millions of dollars | | | | | | | |
| All manufactured products | 94,500 | 116,600 | 155,808 | 166,849 | 151,264 | 143,495 | 158,449 | 161,974 |
| All high-technology products[1] | 34,837 | 43,523 | 54,710 | 60,391 | 58,111 | 60,158 | 65,510 | 68,426 |
| Guided missiles and spacecraft | 635 | 603 | 749 | 557 | 1,133 | 994 | 962 | 827 |
| Communications equipment & electronic components | 6,759 | 8,327 | 10,349 | 11,392 | 11,803 | 12,363 | 14,425 | 13,472 |
| Aircraft and parts | 9,221 | 11,013 | 14,558 | 16,885 | 14,131 | 14,637 | 13,540 | 17,535 |
| Office and computing machines | 4,888 | 6,374 | 6,650 | 9,810 | 10,148 | 11,719 | 14,699 | 15,421 |
| Ordnance and accessories | 539 | 670 | 647 | 676 | 716 | 907 | 845 | 714 |
| Drugs and medicine | 1,492 | 1,652 | 1,983 | 2,220 | 2,329 | 2,564 | 2,672 | 2,724 |
| Industrial inorganic chemicals | 1,999 | 2,575 | 2,892 | 3,111 | 3,017 | 3,070 | 3,543 | 3,335 |
| Professional and scientific instruments | 4,663 | 5,521 | 6,490 | 7,078 | 7,005 | 6,867 | 7,198 | 7,134 |
| Engines, turbines, and parts | 2,362 | 2,935 | 3,603 | 3,831 | 3,601 | 3,016 | 3,234 | 3,127 |
| Plastic materials, synthetics | 2,279 | 3,853 | 4,789 | 4,83[illegible] | 4,228 | 4,021 | 4,392 | 4,137 |
| Other manufacturing products | 59,663 | 73,077 | 101,098 | 106,458 | 93,153 | 83,337 | 92,939 | 93,548 |
| | Value of product shipments | | | | | | | |
| | Millions of dollars | | | | | | | |
| All manufactured products | 1,522,900 | 1,727,200 | 1,852,700 | 2,017,500 | 1,908,300 | 2,045,300 | 2,274,900 | 2,341,200 |
| All high-technology products[1] | 192,578 | 220,373 | 266,409 | 296,639 | 310,179 | 364,930 | 380,109 | 395,818 |
| Guided missiles and spacecraft | 7,535 | 8,801 | 9,974 | 11,795 | 13,[illegible]9 | 15,164 | 17,354 | 17,741 |
| Communications equipment & electronic components | 48,338 | 46,820 | 67,448 | 75,264 | 83,373 | 90,936 | 108,359 | 112,417 |
| Aircraft and parts | 26,094 | 34,862 | 43,322 | 47,173 | 46,665 | 60,407 | 52,847 | 62,884 |
| Office and computing machines | 19,504 | 24,767 | 30,619 | 35,474 | 40,206 | 45,763 | 55,121 | 55,847 |
| Ordnance and accessories | 2,505 | 2,809 | 3,119 | 3,570 | 3,970 | 4,001 | 4,335 | 4,747 |
| Drugs and medicine | 12,277 | 15,866 | 17,772 | 19,877 | 22,840 | 25,017 | 26,877 | 29,532 |
| Industrial inorganic chemicals | 12,512 | 14,257 | 15,570 | 16,295 | 15,[illegible]17 | 33,807 | 17,066 | 16,705 |
| Professional and scientific instruments | 28,560 | 31,359 | 35,865 | 39,490 | 42,404 | 43,561 | 47,196 | 48,313 |
| Engines, turbines, and parts | 11,888 | 12,835 | 13,156 | 14,696 | 12,635 | 12,449 | 14,862 | 14,625 |
| Plastic materials synthetics | 23,467 | 27,997 | 29,564 | 33,004 | [illegible]9,092 | 33,824 | 36,092 | 33,002 |
| Other manufacturing products[2] | 1,330,222 | 1,506,827 | 1,586,291 | 1,720,861 | 1,598,121 | 1,680,370 | 1,894,791 | 1,945,382 |

[1] U S Department of Commerce DOC-3 definition

[2] For Shipments for All Manufacturing Products total shipments by manufacturers is used Shipments of Other Manufactured Products is calculated as the difference between this All Manufactures total and the total shipments of all high-technology products

SOURCES U S Department of Commerce International Trade Administration *U S Trade Performance in 1985 and Outlook* (October 1986) U S Department of Commerce International Trade Administration Office of Trade and Investment Analysis unpublished data Bureau of the Census *Statistical Abstract of the United States 1986* (Washington DC GPO 1987) Bureau of the Census Annual Survey of Manufactures *Value of Product Shipments* (M85(AS) 2) January 1987 and previous editions

See figure O 27 in Overview

## Appendix table 7-3. U.S. direct investment position abroad in manufacturing in selected nations and product groups: 1966-86

| | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Millions of constant 1982 dollars[1] | | | | | | | | | | | | | | | | | | | | |
| Total manufacturing | $59 325 | $63,447 | $66,684 | $71,222 | $73 873 | $77 420 | $82 437 | $89,5[illegible]4 | $94,833 | $94 227 | $96 973 | $92,180 | $96 468 | $100 089 | $104 014 | $98 325 | $83,452 | $79 826 | $79 593 | $85 280 | $93 685 |
| Total major countries | 38,733 | 40 256 | 41 540 | 44.208 | 45.527 | 47 596 | 50 619 | 54 804 | 56.677 | 55 598 | 57 227 | 54,321 | 56.198 | 57 649 | 53,710 | 55 033 | 45.994 | 45.527 | 44 892 | 49.386 | 54.724 |
| Canada | 19 156 | 19 641 | 19.971 | 21 126 | 21 344 | 21 415 | 22 566 | 23 728 | 24 926 | 24 770 | 25.313 | 21.990 | 21 789 | 22 136 | 22.022 | 21.086 | 18 825 | 18 495 | 19 453 | 19 591 | 20.756 |
| France | 3 324 | 3 506 | 3 453 | 3 680 | 4,311 | 4.748 | 5 251 | 5.941 | 6 353 | 6.481 | 6 337 | 6 257 | 6.475 | 6.527 | 6 902 | 5 874 | 4,318 | 3 868 | 3 704 | 4 612 | 5 749 |
| West Germany | 5,000 | 5 442 | 5 696 | 6.488 | 6 365 | 7,001 | 7.823 | 8 966 | 8 921 | 8 983 | 10 633 | 10.797 | 11.559 | 10.914 | 11.266 | 10.695 | 9 089 | 8 880 | 8 213 | 9 607 | 11.3[illegible]3 |
| United Kingdom | 10 206 | 10 437 | 11.023 | 11,292 | 11,680 | 12.228 | 12.431 | 13 345 | 13 660 | 12.738 | 12.263 | 12 351 | 13.131 | 14.541 | 10 054 | 13.935 | 10.704 | 10 514 | 9 741 | 11.457 | 12.222 |
| Japan | 1,047 | 1.230 | 1.397 | 1.621 | 1.827 | 2 204 | 2.549 | 2.824 | 2 817 | 2.625 | 2.681 | 2.925 | 3 244 | 3 532 | 3.467 | 3,444 | 3 058 | 3.769 | 3.778 | 4.119 | 4 634 |
| Other countries | 20.592 | 23.191 | 25.144 | 27.014 | 28 346 | 29.824 | 31.818 | 34,760 | 38.156 | 38 629 | 39.746 | 37 860 | 40.270 | 42.440 | 50 304 | 43 292 | 37.458 | 34 299 | 34.701 | 35 894 | 38 961 |
| Total chemical products | 10 984 | 12.635 | 13.432 | 13 924 | 13 954 | 14 689 | 15 601 | 16 986 | 18 851 | 18.727 | 19 317 | 17.634 | 19.370 | 21.100 | 22.035 | 21,473 | 18 2[illegible]4 | 18.090 | 17 798 | 18 268 | 20.134 |
| Total major countries | 5 947 | 6 322 | 6.494 | 6 604 | 6 652 | 7 174 | 7.554 | 8.359 | 8 953 | 8 855 | 9 063 | 8 077 | 8 999 | 10.130 | 10 254 | 9 951 | 8 636 | 9 026 | 8 748 | 9 214 | 10.190 |
| Canada | 3 026 | 3.189 | 3 239 | 3 260 | 3.141 | 3 274 | 3.405 | 3 567 | 3.797 | 3 824 | 3 904 | 3 343 | 3 568 | 3.775 | 3 969 | 3 958 | 4.178 | 4.37[illegible] | 4 428 | 4 347 | 4.474 |
| France | 469 | 598 | 599 | 669 | 711 | 744 | 839 | 914 | 1.006 | 998 | 1.012 | 1.029 | 1.045 | 1.170 | 1.224 | 1.109 | 797 | 717 | 638 | 712 | 1.036 |
| West Germany | 512 | 556 | 633 | 651 | 702 | 840 | 914 | 1.167 | 1.281 | 1.298 | 1.451 | 1.280 | 1.609 | 1.774 | 1.750 | 1.738 | 1 092 | 1.095 | 891 | 1,014 | 1.248 |
| United Kingdom | 1.691 | 1.692 | 1.675 | 1.619 | 1.670 | 1.845 | 1.871 | 2.103 | 2.263 | 2.128 | 2.104 | 1.735 | 2.023 | 2.558 | 2.495 | 2 330 | 1.791 | 1.731 | 1.669 | 1.959 | 2.033 |
| Japan | 249 | 287 | 347 | 405 | 428 | 471 | 525 | 608 | 606 | 607 | 593 | 691 | 753 | 853 | 817 | 816 | 778 | 1.105 | 1.123 | 1.181 | 1,429 |
| Other countries | 5.037 | 6.313 | 6 939 | 7.320 | 7.302 | 7.515 | 8 047 | 8 627 | 9 898 | 9 872 | 10.254 | 9 557 | 10.371 | 10.970 | 11.780 | 11.522 | 9.638 | 9 064 | 9 050 | [illegible].054 | 9.943 |
| Total machinery | 14.396 | 15.178 | 15 865 | 17.627 | 18 658 | 20.122 | 21.716 | 23 841 | 25 930 | 26 294 | 27.098 | 16 681 | 18 010 | 26 631 | 27.264 | 25 812 | 21.132 | 20 818 | 21.328 | 24.726 | 26.819 |
| Total major countries | 10 255 | 10.746 | NA | NA | NA | 13.659 | 14 668 | 15 662 | 16.481 | 16.439 | 16.567 | 11.785 | 12.681 | 16.331 | 16 616 | 15 314 | 11.925 | 12.012 | 12.325 | 14.518 | 15.765 |
| Canada | 3 847 | 3 962 | 3 997 | 4.382 | 4.218 | 4.261 | 4 541 | 4 693 | 4.970 | 5.129 | 5.147 | 2.307 | 2.390 | 3.686 | 3.688 | 3 852 | 3.302 | 3 535 | 3 787 | 3.645 | 3 684 |
| France | 1.267 | 1.233 | 1.209 | 1.264 | 1.475 | 1,676 | 1.794 | 2 041 | 2.213 | 2.386 | 2.228 | 2.347 | 2.541 | 2.809 | 3.045 | 2.560 | 1.716 | 1.451 | 1.447 | 2.178 | 2.687 |
| West Germany | 1.505 | 1.622 | 2 364 | 2.278 | 2.315 | 2.641 | 2.986 | 3 397 | 3 612 | 3 542 | 3.862 | 2.933 | 3 223 | 4.079 | 3.955 | 3.403 | 3.009 | 3.054 | 2.945 | 3.762 | 4 282 |
| United Kingdom | 3.001 | 3.189 | 3.173 | 3.550 | 3.783 | 3 930 | 3 986 | 4.053 | 4.249 | 4.055 | 3.964 | 2.933 | 3 038 | 4.172 | 4.362 | 3 996 | 2.552 | 2.449 | 2 524 | 3.143 | 3 279 |
| Japan | 635 | 740 | NA | NA | NA | 1.151 | 1.362 | 1.478 | 1.436 | 1.327 | 1.367 | 1.266 | 1.489 | 1.585 | 1.567 | 1.504 | 1.346 | 1.523 | 1.622 | 1.790 | 1.832 |
| Other countries | 4 142 | 4 432 | NA | NA | NA | 6 462 | 7.049 | 8.179 | 9.450 | 9 855 | 10 531 | 4.896 | 5.330 | 10 300 | 10 649 | 10.498 | 9.207 | 8.806 | 9 004 | 10.208 | 11.054 |
| | Millions of dollars | | | | | | | | | | | | | | | | | | | | |
| Total manufacturing | $20.740 | $22.803 | $25 160 | $28 332 | $31.049 | $34.359 | $38 325 | $44 370 | $51.172 | $55 886 | $61.161 | $62 019 | $69 669 | $78 640 | $89.161 | $92 386 | $83.452 | $82.907 | $85 865 | $95.101 | $107.241 |
| Total major countries | 13 541 | 14.468 | 15.673 | 17.586 | 19.135 | 21.123 | 23 533 | 27.150 | 30.583 | 32.975 | 36 093 | 36 547 | 40 586 | 45.295 | 46.040 | 51.709 | 45.994 | 47.284 | 48.430 | 55.075 | 62.642 |
| Canada | 6 697 | 7.059 | 7.535 | 8.404 | 8.971 | 9 504 | 10.491 | 11.755 | 13.450 | 14.691 | 15.965 | 14.795 | 15.736 | 17.392 | 18.877 | 19 812 | 18 825 | 19 209 | 20 986 | 21.848 | 23.759 |
| France | 1.162 | 1.260 | 1.303 | 1.464 | 1.812 | 2.107 | 2.441 | 2.943 | 3.428 | 3 844 | 3 997 | 4 210 | 4.676 | 5.128 | 5 916 | 5.519 | 4.318 | 4 017 | 3.996 | 5.143 | 6.581 |
| West Germany | 1.748 | 1.956 | 2.149 | 2.581 | 2.675 | 3 107 | 3 637 | 4.442 | 4.814 | 5.328 | 6.706 | 7.264 | 8 348 | 8 575 | 9.657 | 10.049 | 9.089 | 9.223 | 8 860 | 10.714 | 13 007 |
| United Kingdom | 3.568 | 3.751 | 4.159 | 4.492 | 4 909 | 5.427 | 5.779 | 6 611 | 7 371 | 7.555 | 7.734 | 8 310 | 9.483 | 11.425 | 8 618 | 13 093 | 10.704 | 10 920 | 10 512 | 12.777 | 13 990 |
| Japan | 366 | 442 | 527 | 645 | 768 | 978 | 1.185 | 1 399 | 1.520 | 1.557 | 1.691 | 1.968 | 2.343 | 2.775 | 2.972 | [illegible] 236 | 3 058 | 3 915 | 4.076 | 4.593 | 5 305 |
| Other countries | 7.199 | 8.335 | 9.487 | 10.746 | 11.914 | 13 236 | 14.792 | 17 220 | 20 589 | 22.911 | 25 068 | 25.472 | 29.083 | 33 345 | 43.121 | 40 677 | 37.458 | 35 623 | 37.435 | 40 029 | 41.599 |
| Total chemical products | 3 840 | 4.541 | 5 068 | 5 539 | 5 865 | 6 519 | 7 253 | 8 415 | 10.172 | 11.107 | 12.183 | 11.864 | 13 989 | 16 578 | 18.863 | 20.176 | 18 274 | 18.788 | 19 200 | 20 372 | 23.047 |
| Total major countries | 2 079 | 2.272 | 2.450 | 2.627 | 2.796 | 3.184 | 3 512 | 4.141 | 4 831 | 5 252 | 5.716 | 5.434 | 6.499 | 7.959 | 8 790 | 9.350 | 8 636 | 9 374 | 9.437 | 10 275 | 11.665 |
| Canada | 1.058 | 1.146 | 1.222 | 1.297 | 1.320 | 1.453 | 1.583 | 1.767 | 2.049 | 2.268 | 2.462 | 2.249 | 2.577 | 2.966 | 3.402 | 3.719 | 4.178 | 4.546 | 4.777 | 4 848 | 5.121 |
| France | 164 | 215 | 226 | 266 | 299 | 330 | 390 | 453 | 543 | 592 | 638 | 692 | 755 | 919 | 1.049 | 1.042 | 797 | 745 | 688 | 794 | 1.152 |
| West Germany | 179 | 200 | 239 | 259 | 295 | 373 | 425 | 578 | 691 | 770 | 915 | 861 | 1.162 | 1.394 | 1.500 | 1.633 | 1.092 | 1.137 | 961 | 1.131 | 1.429 |
| United Kingdom | 591 | 608 | 632 | 644 | 702 | 819 | 870 | 1.012 | 1.221 | 1 262 | 1 327 | 1.167 | 1.461 | 2.010 | 2.139 | 2.189 | 1.791 | 1.798 | 1.800 | 2.185 | 2.327 |
| Japan | 87 | 103 | 131 | 161 | 180 | 209 | 244 | 301 | 327 | 360 | 374 | 465 | 514 | 670 | 700 | 767 | 778 | 1.148 | 1.211 | 1 317 | 1.636 |
| Other countries | 1.761 | 2.269 | 2.618 | 2.912 | 3.069 | 3 335 | 3 741 | 4 274 | 5.341 | 5 855 | 6.467 | 6 430 | 7.490 | 8 619 | 10 098 | 10 826 | 9 638 | 9 414 | 9.763 | 10 097 | 11.382 |
| Total machinery | 5.033 | 5.455 | 5 986 | 7.012 | 7.842 | 8 930 | 10.096 | 11 811 | 13 992 | 15 595 | 17.091 | 11.223 | 13 007 | 20.924 | 23 371 | 24.253 | 21 132 | 21.622 | 23 009 | 27.574 | 30.700 |
| Total major countries | 3.585 | 3.862 | NA | NA | NA | 6 062 | 6 819 | 7.759 | 8 893 | 9.750 | 10.449 | 7.929 | 9.158 | 12.831 | 14.243 | 14 389 | 11.925 | 12.476 | 13 296 | 16.190 | 18 046 |
| Canada | 1.345 | 1.424 | 1.508 | 1.743 | 1 773 | 1.891 | 2 111 | 2 325 | 2.682 | 3 042 | 3.246 | 1 552 | 1.726 | 2.896 | 3.161 | 3 619 | 3 302 | 3 67[illegible] | 4 085 | 4.065 | 4.217 |
| France | 443 | 443 | 456 | 503 | 620 | 744 | 834 | 1.011 | 1 194 | 1 415 | [illegible].405 | 1 579 | 1.835 | 2.207 | 2.610 | [illegible].405 | 1.716 | 1.507 | 1 561 | 2.429 | 3.076 |
| West Germany | 526 | 583 | 892 | 906 | 973 | 1 172 | 1 388 | 1.683 | 1 949 | 2.101 | 2.436 | 1.973 | 2.328 | 3 205 | 3 390 | 3.197 | 3 009 | 3 172 | 3.177 | 4.195 | 4.902 |
| United Kingdom | 1.049 | 1 146 | 1.197 | 1.412 | 1 590 | 1.744 | 1.853 | 2.008 | 2.293 | 2 405 | 2.500 | 1 973 | 2.194 | 3.278 | 3.739 | 3.755 | 2.552 | 2 544 | 2.723 | 3 505 | 3.754 |
| Japan | 222 | 266 | NA | NA | NA | 511 | 633 | 732 | 775 | 787 | 862 | 852 | 1.075 | 1.245 | 1.343 | 1 413 | 1.346 | 1 582 | 1.750 | 1 996 | 2.097 |
| Other countries | 1,448 | 1.593 | NA | NA | NA | 2 868 | 3 277 | 4.052 | 5.099 | 5 845 | 6 642 | 3 294 | [illegible].849 | 8 093 | 9.128 | 9.864 | 9 207 | 9 146 | 9.713 | 11 384 | 12.654 |

Note: Certain data are withheld by the U.S. Commerce Department to avoid disclosure of data for individual companies

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

SOURCES. U.S Department of Commerce, Bureau of Economic Analysis, *Selected Data on U.S. Direct Investment Abroad, 1966-78* (1980). U S Department of Commerce, Bureau of ... *ness* (February 1981), pp.50-51. U.S Department of Commerce, Bureau of Economic Analysis. *Survey of Current Business* (annual, August issues). U.S. Department of Commerce, statistics

See figures 7-1, 7-2.

**Appendix table 7-4. Operations of overseas affiliates of U.S. corporations, selected high-technology manufacturing and service industries: 1984**

| Industry of affiliates | Affiliate sales | Affiliate profits | Exports shipped to affiliates | Net affiliate sales[1] | Total U.S. exports[2] | Total foreign operations: exports + net affiliate sales | Total Shipments[3] | Total revenues: domestic shipments + net affiliate sales |
|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | |
| All manufacturing industries | 369,333 | 16,387 | 47,260 | 322,073 | 158,449 | 480,522 | 2,253,847 | 2,575,920 |
| High technology manufacturing industries[1] | 117,009 | 7,743 | 15,968 | 101,041 | 50,163 | 151,204 | 378,135 | 479,176 |
| Radio, television and communications equipment | 8,814 | 376 | 1,174 | 7,640 | 7,762 | 15,402 | 67,012 | 74,652 |
| Electronic components & accessories | 13,600 | 967 | 3,977 | 9,623 | 6,663 | 16,286 | 47,983 | 57,606 |
| Office & computing machines | 30,914 | 2,870 | 4,476 | 26,438 | 14,699 | 41,137 | 59,715 | 86,153 |
| Drugs & medicines | 14,477 | 1,200 | 1,238 | 13,239 | 2,672 | 15,911 | 28,967 | 42,206 |
| Industrial chemicals & synthetics | 34,218 | 1,717 | 2,504 | 31,714 | 7,935 | 39,649 | 99,518 | 131,232 |
| Instruments & related products | 12,759 | 617 | 2,317 | 10,442 | 7,198 | 17,640 | 59,447 | 69,889 |
| Engines & turbines | 2,227 | (4) | 282 | 1,945 | 3,234 | 5,179 | 15,494 | 17,439 |
| Other manufacturing industries | 252,324 | 8,644 | 31,292 | 221,032 | 108,286 | 329,318 | 1,875,712 | 2,096,744 |
| All service industries | 19,888 | 1,350 | 161 | 19,727 | 70,950 | 90,677 | 3,457,300 | 3,477,027 |
| Computer & data processing services | 1,105 | 28 | 47 | 1,058 | 3,500 | 4,558 | 40,542 | 41,600 |
| R&D and testing laboratories | 282 | 14 | NA | NA | NA | NA | NA | NA |
| Engineering, architectural, and surveying services | 3,029 | 155 | 3 | 3,026 | 1,200 | 4,226 | 40,200 | 43,226 |
| Other service industries | 15,472 | 1,153 | NA | NA | NA | NA | NA | NA |
| | Percent | | | | | | | |
| All manufacturing industries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100 |
| High technology manufacturing industries[1] | 31.7 | 47.3 | 33.8 | 31.4 | 31.7 | 31.5 | 16.8 | 19 |
| Radio, television and communications equipment | 2.4 | 2.3 | 2.5 | 2.4 | 4.9 | 3.2 | 3.0 | 3 |
| Electronic components & accessories | 3.7 | 5.9 | 8.4 | 3.0 | 4.2 | 3.4 | 2.1 | 2 |
| Office & computing machines | 8.4 | 17.5 | 9.5 | 8.2 | 9.3 | 8.6 | 2.6 | 3 |
| Drugs & medicines | 3.9 | 7.3 | 2.6 | 4.1 | 1.7 | 3.3 | 1.3 | 2 |
| Industrial chemicals & synthetics | 9.3 | 10.5 | 5.3 | 9.8 | 5.0 | 8.3 | 4.4 | 5 |
| Instruments & related products | 3.5 | 3.8 | 4.9 | 3.2 | 4.5 | 3.7 | 2.6 | 3 |
| Engines & turbines | 0.6 | 0.0 | 0.6 | 0.6 | 2.0 | 1.1 | 0.7 | 1 |
| Other manufacturing industries | 68.3 | 52.7 | 66.2 | 68.6 | 68.3 | 68.5 | 83.2 | 81 |

*(continued)*

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**Appendix table 7-4. (Continued)**

| Industry of affiliates | Net affiliate sales as a percent of foreign operations | Net affiliate sales as a percent of total revenues | Foreign operations as a percent of total revenues |
|---|---|---|---|
| | Percent | | |
| All manufacturing industries ... | 67.0 | 12.5 | 18.7 |
| High technology manufacturing industries[1] . | 66.8 | 21.1 | 31.6 |
| Radio, television and communications equipment ............ | 49.6 | 10.2 | 20.6 |
| Electronic components & accessories ........... | 59.1 | 16.7 | 28.3 |
| Office & computing machines ............. | 64.3 | 30.7 | 47.7 |
| Drugs & medicines ....... | 83.2 | 31.4 | 37.7 |
| Industrial chemicals & synthetics ............. | 80.0 | 24.2 | 30.2 |
| Instruments & related products .............. | 59.2 | 14.9 | 25.2 |
| Engines & turbines ....... | 37.6 | 11.2 | 29.7 |
| Other manufacturing industries ............... | 67.1 | 10.5 | 15.7 |
| All service industries ....... | 21.8 | 0.6 | 2.6 |
| Computer & data processing services .... | 23.2 | 2.5 | 11.0 |
| R&D and testing laboratories ........... | NA | NA | NA |
| Engineering, architectural, and surveying services . | 71.6 | 7.0 | 9.8 |
| Other service industries ... | NA | NA | NA |

[1] Affiliate sales less U.S. exports shipped to affiliates.

[2] Manufacturing exports are broken down by SIC product groups. Radio, television, and communications equipment and Electronic components & accessories are estimated by dividing U.S. exports of communications equipment & electronic components according to the distribution of affiliate sales in the two industries. Service exports are the midrange of the OTA estimates.

[3] Shipments of services are the OTA estimates for Domestic Industry.

SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and their Foreign Affiliates*, 1986), Tables 2, 17; U.S. Department of Commerce, International Trade Administration, *United States Trade Performance in 1985 and Outlook* (October, 1986); U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures: Statistics for Industry Groups and Industries*, M84(AS)-1 (July, 1986); U.S. Congress Office of Technology Assessment, *Trade in Services: Exports and Foreign Revenues—Special Report*, OTA-ITE-316 (September, 1986)

See figures 7-3, 7-4.

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Appendix table 7-5. Foreign direct investment position in the United States in manufacturing, by nationality of parent company, in selected industries: 1979-86

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|---|
| | Millions of constant 1982 dollars[1] | | | | | | | |
| Total manufacturing | $26,570 | $38,510 | $43,139 | $44,065 | $45,894 | $48,085 | $53,597 | $59,673 |
| Total major countries | 18.855 | 16,681 | 40,103 | 40.057 | 41.646 | 44,012 | 48,930 | 53,811 |
| Canada | 4,601 | 11,752 | 3,593 | 3,500 | 3.190 | 3,820 | 4,144 | 4,725 |
| France | 1,359 | NA | 5.177 | 4,974 | 5,283 | 4,983 | 5,143 | 5,251 |
| West Germany | 3,106 | NA | 4,469 | 4,239 | 4.320 | 4.074 | 5.411 | 6,958 |
| Netherlands | 4,458 | NA | 9,598 | 9,901 | 10,805 | 11.600 | 12,010 | 12,900 |
| United Kingdom | 4,411 | NA | 8,091 | 8,504 | 8,878 | 9,022 | 10,513 | 13,151 |
| Japan | 919 | 4,929 | 1,406 | 1,624 | 1.545 | 2,283 | 2,463 | 2,645 |
| Switzerland | NA | NA | 3,489 | 3,584 | 4,010 | 4,431 | 6,190 | 6,795 |
| Netherlands Antilles | NA | NA | 4,282 | 3.731 | 3,614 | 3,798 | 3,057 | 1,384 |
| Other countries | 7,715 | 21,829 | 3,035 | 4,008 | 4,247 | 4,073 | 4,668 | 5,862 |
| Total chemical products | 9,012 | 12,178 | 14,582 | 14,377 | 15,180 | 15.438 | 16,943 | 20,158 |
| Total major countries | 5,460 | NA | 8.858 | 13,727 | 14,433 | 14.577 | 16,264 | 19,425 |
| Canada | 129 | NA | 102 | 125 | 96 | 102 | 130 | 235 |
| France | 313 | NA | NA | 2,915 | 2,860 | 2,691 | 2,694 | 2.710 |
| West Germany | 2,089 | NA | 2,090 | 1,972 | 2.109 | 2,105 | 3,352 | 4,184 |
| Netherlands | 1.123 | NA | 2,211 | 2,237 | 2,814 | 3,095 | 3,203 | 4,018 |
| United Kingdom | 1.569 | NA | 2,900 | 3,079 | 3,082 | 3,103 | 3,270 | 4,748 |
| Japan | 238 | NA | 265 | 252 | 272 | 234 | 241 | 253 |
| Switzerland | NA | NA | 1,290 | 1,359 | 1,631 | 1.844 | 1,936 | 1,868 |
| Netherlands Antilles | NA | NA | NA | 1,788 | 1,568 | 1.403 | 1,438 | 1,408 |
| Other countries | 3,552 | NA | 5,724 | 650 | 747 | 860 | 679 | 733 |
| Total machinery | 4,255 | 8,160 | 8,830 | 8,595 | 8.288 | 8,987 | 8,306 | 8,797 |
| Total major countries | 3,489 | NA | 6,656 | 6,518 | 6,263 | 6,720 | 6,879 | 7,847 |
| Canada | 1,493 | NA | 1,253 | 988 | 978 | 1,114 | 1.088 | 1,404 |
| France | 69 | NA | 0 | 75 | 106 | 149 | 192 | 189 |
| West Germany | 263 | NA | 1,207 | 1,254 | 1,039 | 900 | 928 | 1,519 |
| Netherlands | 985 | NA | 1,659 | 1,847 | 1,809 | 1,804 | 1,617 | 1.726 |
| United Kingdom | 476 | NA | 1,497 | 1,338 | 1,363 | 1,615 | 1,777 | 1,534 |
| Japan | 202 | NA | 442 | 423 | 449 | 583 | 643 | 765 |
| Switzerland | NA | NA | 598 | 593 | 519 | 554 | 631 | 711 |
| Netherlands Antilles | NA | NA | NA | NA | NA | NA | NA | NA |
| Other countries | 766 | NA | 2,174 | 2,077 | 2,025 | 2,268 | 1.428 | 950 |

Note: Certain data are withheld by the U.S Commerce Department to avoid disclosure of data for individual companies

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

SOURCES: U.S Department of Commerce, Bureau of Economic Analysis, *Selected Data on U S Direct Investment Abroad. 1966-78 (1980)*. U S Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (February 1981), pp 50-51 U S Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (annual, August issues)

See figure 7-5.

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## Appendix table 7-6. Foreign direct investment position in the U.S., high-technology industries: 1980-86

| Industries | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| | Millions of 1982 dollars[1] | | | | | | |
| All manufacturing industries | 38,510 | 43,139 | 44,065 | 45,894 | 48,018 | 53,429 | 59,673 |
| High-technology industries[2] | 13,419 | 16,469 | 16,830 | 17,850 | 18,208 | 19,463 | 22,756 |
| Radio, television, and communications equipment | 1,288 | 1,668 | 1,744 | 1,736 | 1,838 | 1,766 | 2,850 |
| Electronic components & accesories | 1,776 | 2,029 | 2,199 | 2,269 | 2,541 | 1,948 | 819 |
| Office and computing machines | 517 | 576 | 685 | 730 | 1,057 | 919 | 864 |
| Drugs and medicine | 1,777 | 1,681 | 1,796 | 2,053 | 2,127 | 2,177 | 2,922 |
| Industrial chemicals and synthetics | 7,290 | 9,811 | 9,607 | 10,112 | 9,855 | 11,517 | 13,378 |
| Instruments and related products | 685 | 624 | 705 | 855 | 673 | 941 | 1,546 |
| Engines and turbines | 87 | 82 | 94 | 95 | 117 | 195 | 378 |
| Other manufacturing industries | 25,091 | 26,670 | 27,235 | 28,044 | 29,810 | 33,966 | 36,917 |
| All service industries | 1,270 | 1,415 | 1,899 | 2,005 | 2,298 | 2,639 | 5,250 |
| Computer & data processing services | 62 | 64 | 77 | 126 | 224 | 230 | 301 |
| R&D and testing laboratories | 64 | 61 | 63 | 72 | 70 | 74 | 83 |
| Engineering, architectural & surveying services | 150 | 152 | 155 | 117 | 157 | 179 | 722 |
| Other service industries | 994 | 1,139 | 1,604 | 1,690 | 1,846 | 2,155 | 4,145 |
| | Millions of dollars | | | | | | |
| All manufacturing industries | 33,011 | 40,533 | 44,065 | 47,665 | 51,802 | 59,584 | 68,057 |
| High-technology industries[2] | 11,503 | 15,474 | 16,830 | 18,539 | 19,643 | 21,705 | 25,953 |
| Radio, television, and communications equipment | 1,104 | 1,567 | 1,744 | 1,803 | 1,983 | 1,969 | 3,250 |
| Electronic components & accesories | 1,522 | 1,906 | 2,199 | 2,3[illegible] | 2,741 | 2,172 | 934 |
| Office and computing machines | 443 | 541 | 685 | 7[illegible]8 | 1,140 | 1,025 | 985 |
| Drugs and medicine | 1,523 | 1,579 | 1,796 | 2,132 | 2,295 | 2,428 | 3,332 |
| Industrial chemicals and synthetics | 6,249 | 9,218 | 9,607 | 10,502 | 10,632 | 12,844 | 15,258 |
| Instruments and related products | 587 | 586 | 705 | 888 | 726 | 1,049 | 1,763 |
| Engines and turbines | 75 | 77 | 94 | 99 | 126 | 218 | 431 |
| Other manufacturing industries | 21,508 | 25,059 | 27,235 | 29,126 | 32,159 | 37,879 | 42,104 |
| All service industries | 1,089 | 1,330 | 1,899 | 2,082 | 2,479 | 2,943 | 5,988 |
| Computer & data processing services | 53 | 60 | 77 | 131 | 242 | 257 | 343 |
| R&D and testing laboratories | 55 | 57 | 63 | 75 | 76 | 83 | 95 |
| Engineering, architectural & surveying services | 129 | 143 | 155 | 121 | 169 | 200 | 823 |
| Other service industries | 852 | 1,070 | 1,604 | 1,755 | 1,992 | 2,403 | 4,727 |

[1] GNP implicit price deflators used to convert current dollars to constant 1982 dollars

[2] U S. Department of Commerce DOC-3 definitions.

SOURCE: U S. Department of Commerce. Bureau of Economic Analysis. Foreign Direct Investment in the United States. Detail for Position and Balance of Payments Flows". *Survey of Current Business* (annual. August issues)

See figure 7-6.



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Appendix table 7-7. U.S. receipts and payments of royalties and fees associated with unaffiliated foreign residents: 1972-85

| Years | All countries | Canada | West Germany | France | United Kingdom | Other Europe | Japan | Other countries |
|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | |
| Receipts: | | | | | | | | |
| 1972 | $655 | $38 | $56 | $42 | $63 | $150 | $240 | $66 |
| 1973 | 712 | 32 | 63 | 43 | 75 | 121 | 273 | 105 |
| 1974 | 751 | 38 | 78 | 46 | 71 | 137 | 249 | 132 |
| 1975 | 757 | 38 | 81 | 47 | 79 | 151 | 219 | 142 |
| 1976 | 822 | 45 | 83 | 57 | 72 | 157 | 246 | 162 |
| 1977 | 1,037 | 42 | 92 | 48 | 82 | 210 | 275 | 288 |
| 1978 | 1,180 | 61 | 119 | 47 | 93 | 206 | 343 | 311 |
| 1979 | 1,204 | 43 | 109 | 54 | 102 | 224 | 343 | 329 |
| 1980 | 1,305 | 68 | 145 | 144 | 113 | 120 | 403 | 312 |
| 1981 | 1,490 | 69 | 101 | 133 | 119 | 277 | 423 | 368 |
| 1982 | 1,669 | 71 | 105 | 119 | 122 | 266 | 502 | 484 |
| 1983 | 1,625 | 75 | 133 | 135 | 133 | 245 | 523 | 381 |
| 1984 | 1,619 | 82 | 118 | 103 | 132 | 274 | 549 | 361 |
| 1985 | 1,700 | 86 | 124 | 108 | 138 | 288 | 576 | 380 |
| Payments: | | | | | | | | |
| 1972 | 139 | 6 | 29 | 13 | 44 | 35 | 6 | 6 |
| 1973 | 176 | 6 | 37 | 16 | 53 | 41 | 13 | 10 |
| 1974 | 186 | 7 | 34 | 14 | 67 | 43 | 12 | 9 |
| 1975 | 186 | 9 | 32 | 15 | 76 | 40 | 9 | 5 |
| 1976 | 189 | 9 | 34 | 14 | 77 | 35 | 13 | 7 |
| 1977 | 262 | 8 | 31 | 14 | 72 | 38 | 16 | 83 |
| 1978 | 277 | 10 | 27 | 16 | 84 | 47 | 15 | 78 |
| 1979 | 309 | 16 | 40 | 17 | 93 | 51 | 15 | 77 |
| 1980 | 297 | 18 | 61 | 31 | 96 | 55 | 20 | 16 |
| 1981 | 289 | 13 | 43 | 30 | 99 | 52 | 37 | 15 |
| 1982 | 292 | 10 | 35 | 22 | 94 | 56 | 31 | 44 |
| 1983 | 315 | 10 | 35 | 29 | 90 | 77 | 53 | 21 |
| 1984 | 362 | 11 | 58 | 35 | 85 | 88 | 63 | 22 |
| 1985 | 380 | 12 | 65 | 37 | 89 | 88 | 66 | 23 |

(continued)

## Appendix table 7-7. (Continued)

| Years | All countries | Canada | West Germany | France | United Kingdom | Other Europe | Japan | Other countries |
|---|---|---|---|---|---|---|---|---|
| | Millions of dollars | | | | | | | |
| | Millions of constant 1982 dollars[1] | | | | | | | |
| Receipts: | | | | | | | | |
| 1972 | $1,409 | $82 | $120 | $90 | $136 | $323 | $516 | $142 |
| 1973 | 1,437 | 65 | 127 | 87 | 151 | 244 | 551 | 212 |
| 1974 | 1,392 | 70 | 145 | 85 | 132 | 254 | 461 | 245 |
| 1975 | 1,276 | 64 | 137 | 79 | 133 | 255 | 369 | 239 |
| 1976 | 1,303 | 71 | 132 | 90 | 114 | 249 | 390 | 257 |
| 1977 | 1,541 | 62 | 137 | 71 | 122 | 312 | 409 | 428 |
| 1978 | 1,634 | 84 | 165 | 65 | 129 | 285 | 475 | 431 |
| 1979 | 1,532 | 55 | 139 | 69 | 130 | 285 | 437 | 419 |
| 1980 | 1,522 | 79 | 169 | 168 | 132 | 140 | 470 | 364 |
| 1981 | 1,586 | 73 | 107 | 142 | 127 | 295 | 450 | 392 |
| 1982 | 1,669 | 71 | 105 | 119 | 122 | 266 | 502 | 484 |
| 1983 | 1,565 | 72 | 128 | 130 | 128 | 236 | 504 | 367 |
| 1984 | 1,501 | 76 | 109 | 95 | 122 | 254 | 509 | 335 |
| 1985 | 1,524 | 77 | 111 | 97 | 124 | 258 | 516 | 341 |
| Payments: | | | | | | | | |
| 1972 | $299 | $13 | $62 | $28 | $95 | $75 | $13 | $13 |
| 1973 | 355 | 12 | 75 | 32 | 107 | 83 | 26 | 20 |
| 1974 | 345 | 13 | 63 | 26 | 124 | 80 | 22 | 17 |
| 1975 | 314 | 15 | 54 | 25 | 128 | 67 | 15 | 8 |
| 1976 | 300 | 14 | 54 | 22 | 122 | 55 | 21 | 11 |
| 1977 | 389 | 12 | 46 | 21 | 107 | 56 | 24 | 123 |
| 1978 | 384 | 14 | 37 | 22 | 116 | 65 | 21 | 108 |
| 1979 | 393 | 20 | 51 | 22 | 118 | 65 | 19 | 98 |
| 1980 | 346 | 21 | 71 | 36 | 112 | 64 | 23 | 19 |
| 1981 | 308 | 14 | 46 | 32 | 105 | 55 | 39 | 16 |
| 1982 | 292 | 10 | 35 | 22 | 94 | 56 | 31 | 44 |
| 1983 | 303 | 10 | 34 | 28 | 87 | 74 | 51 | 20 |
| 1984 | 336 | 10 | 54 | 32 | 79 | 82 | 58 | 20 |
| 1985 | 341 | 11 | 58 | 33 | 80 | 79 | 59 | 21 |
| Balance: | | | | | | | | |
| 1972 | $1,110 | $69 | $58 | $62 | $41 | $247 | $503 | $129 |
| 1973 | 1082 | 52 | 52 | 55 | 44 | 161 | 525 | 192 |
| 1974 | 1047 | 57 | 82 | 59 | 7 | 174 | 439 | 228 |
| 1975 | 963 | 49 | 83 | 54 | 5 | 187 | 354 | 231 |
| 1976 | 1004 | 57 | 78 | 68 | -8 | 193 | 369 | 246 |
| 1977 | 1152 | 51 | 91 | 51 | 15 | 256 | 385 | 305 |
| 1978 | 1250 | 71 | 127 | 43 | 12 | 220 | 454 | 323 |
| 1979 | 1139 | 34 | 88 | 47 | 11 | 220 | 417 | 321 |
| 1980 | 1176 | 58 | 98 | 132 | 20 | 76 | 447 | 345 |
| 1981 | 1278 | 60 | 62 | 110 | 21 | 239 | 411 | 376 |
| 1982 | 1377 | 61 | 70 | 97 | 28 | 210 | 471 | 440 |
| 1983 | 1261 | 63 | 94 | 102 | 41 | 162 | 453 | 347 |
| 1984 | 1165 | 66 | 56 | 63 | 44 | 172 | 451 | 314 |
| 1985 | 1184 | 66 | 53 | 64 | 44 | 179 | 457 | 320 |

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, unpublished data

See figure 7-7.

## Appendix table 7-8. Technology sales agreements between Japan and the United States and other countries, new and old agreements, number of agreements, and payments made: 1975-85

| Year | United States | | Other major countries | |
|---|---|---|---|---|
| | New agreements | Old, in force agreements | New agreements | Old, in force agreements |
| | Number of agreements | | | |
| 1975 | 58 | 198 | 444 | 25 |
| 1976 | 166 | 251 | 515 | 29 |
| 1977 | 88 | 246 | 516 | 27 |
| 1978 | 102 | 281 | 625 | 41 |
| 1979 | 144 | 319 | 629 | 20 |
| 1980 | 164 | 488 | 872 | 29 |
| 1981 | 182 | 468 | 935 | 36 |
| 1982 | 206 | 448 | 872 | 39 |
| 1983 | 386 | 683 | 1,768 | 170 |
| 1984 | 197 | 554 | 1,150 | 88 |
| 1985 | 261 | 635 | 1,248 | 52 |
| | Value of agreements Millions of constant 1980 Yen | | | |
| 1975 | 1,652 | 7,116 | 2,668 | 1,906 |
| 1976 | 2,254 | 7,117 | 1,423 | 3,559 |
| 1977 | 3,027 | 7,063 | 2,018 | 2,915 |
| 1978 | 6,524 | 7,487 | 2,460 | 2,995 |
| 1979 | 6,750 | 13,188 | 1,661 | 4,258 |
| 1980 | 6,100 | 16,000 | 3,600 | 5,000 |
| 1981 | 10,271 | 21,318 | 4,845 | 5,911 |
| 1982 | 8,183 | 25,785 | 7,422 | 10,466 |
| 1983 | 11,143 | 39,471 | 4,816 | 10,859 |
| 1984 | 11,269 | 50,182 | 4,441 | 11,837 |
| 1985 | 6,743 | 41,495 | 9,303 | 12,443 |

SOURCES: Statistics Bureau, Management and Coordination Agency, Government of Japan, unpublished statistics; updates and deflators provided by National Science Foundation, Division of International Programs, Tokyo Office

See table 7-1 in text

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## Appendix table 7-9. Technology purchase agreements between Japan and the United States and other countries, new and old agreements, number of agreements, and payments made: 1975-85

| Year | United States | | Other major countries | |
|---|---|---|---|---|
| | New agreements | Old, in force agreements | New agreements | Old, in force agreements |
| | Number of Agreements | | | |
| 5 | 476 | 3,076 | 208 | 2,160 |
| 1976 | 313 | 3,042 | 163 | 1,622 |
| 1977 | 357 | 6,097 | 187 | 1,717 |
| 1978 | 497 | 3,136 | 331 | 1,611 |
| 1979 | 680 | 3,402 | 177 | 1,639 |
| 1981 | 396 | 3,696 | 179 | 1,672 |
| 1982 | 443 | 3,619 | 253 | 1,423 |
| 1983 | 554 | 4,144 | 235 | 1,523 |
| 1984 | 591 | 3,744 | 272 | 1,590 |
| 1985 | 716 | 4,006 | 297 | 1,489 |
| | Value of Agreements Millions of constant 1980 Yen | | | |
| 1975 | 9,403 | 126,302 | 4,193 | 46,633 |
| 1976 | 15,421 | 120,522 | 3,321 | 41,637 |
| 1977 | 8,969 | 123,655 | 6,054 | 44,283 |
| 1978 | 28,984 | 102,674 | 6,631 | 37,968 |
| 1979 | 22,118 | 137,279 | 3,323 | 52,440 |
| 1980 | 19,900 | 134,000 | 4,900 | 47,500 |
| 1981 | 16,844 | 149,468 | 2,323 | 43,950 |
| 1982 | 32,414 | 145,342 | 4,943 | 46,483 |
| 1983 | 32,453 | 147,830 | 5,189 | 39,434 |
| 1984 | 22,050 | 157,787 | 4,336 | 34,826 |
| 1985 | 21,889 | 169,635 | 4,884 | 31,735 |

SOURCES. Statistics Bureau. Management and Coordination Agency. Government of Japan, unpublished statistics. updates and deflators provided by National Science Foundation, Division of International Programs, Tokyo Office

See table 7-1 in text.

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Appendix table 7-10. Exports of high-technology products[1], by selected countries: 1965-84

| Year | All Countries[2] | France | West Germany | Japan | United Kingdom | United States | Other |
|---|---|---|---|---|---|---|---|
| | Billions of dollars | | | | | | |
| 1965 ........ | 16.42 | 1.23 | 2.70 | 1.19 | 2.01 | 4.66 | 4.63 |
| 1966 ........ | 18.86 | 1.45 | 3.08 | 1.62 | 2.41 | 5.19 | 5.11 |
| 1967 ........ | 21.19 | 1.61 | 3.44 | 1.89 | 2.40 | 6.11 | 5.74 |
| 1968 ........ | 24.96 | 1.72 | 3.94 | 2.50 | 2.63 | 7.42 | 6.74 |
| 1969 ........ | 29.40 | 2.06 | 4.71 | 3.36 | 2.99 | 8.50 | 7.79 |
| 1970 ........ | 35.59 | 2.47 | 5.76 | 4.19 | 3.52 | 10.25 | 9.40 |
| 1971 ........ | 37.70 | 2.82 | 3.51 | 5.13 | 4.21 | 11.23 | 10.79 |
| 1972 ........ | 48.06 | 3.52 | 8.03 | 6.60 | 4.90 | 11.82 | 13.19 |
| 1973 ........ | 64.62 | 4.90 | 11.67 | 8.54 | 6.19 | 15.99 | 17.33 |
| 1974 ........ | 83.92 | 6.18 | 14.99 | 10.72 | 7.87 | 21.74 | 22.43 |
| 1975 ........ | 88.32 | 7.20 | 14.57 | 10.68 | 8.86 | 23.19 | 23.82 |
| 1976 ........ | 102.79 | 8.58 | 17.59 | 15.25 | 9.25 | 25.97 | 26.15 |
| 1977 ........ | 117.25 | 9.79 | 20.22 | 18.07 | 11.08 | 27.75 | 30.33 |
| 1978 ........ | 147.00 | 12.15 | 24.77 | 23.50 | 14.56 | 34.84 | 37.18 |
| 1979 ........ | 179.67 | 16.25 | 30.25 | 25.76 | 18.07 | 43.52 | 45.83 |
| 1980 ........ | 214.86 | 17.58 | 33.88 | 32.58 | 23.56 | 54.71 | 52.54 |
| 1981 ........ | 219.37 | 16.60 | 31.56 | 40.26 | 20.39 | 60.39 | 50.17 |
| 1982 ........ | 202.67 | 16.59 | 21.48 | 37.15 | 20.45 | 58.11 | 48.88 |
| 1983 ........ | 223.44 | 16.71 | 31.81 | 43.96 | 19.46 | 60.16 | 51.34 |
| 1984 ........ | 248.30 | 18.17 | 33.68 | 55.22 | 20.88 | 65.51 | 54.83 |
| | Billions of 1982 Dollars[3] | | | | | | |
| 1965 ........ | 48.61 | 3.64 | 8.01 | 3.52 | 5.94 | 13.80 | 13.70 |
| 1966 ........ | 53.96 | 4.15 | 8.82 | 4.64 | 6.90 | 14.83 | 14.62 |
| 1967 ........ | 58.96 | 4.48 | 9.57 | 5.25 | 6.67 | 17.01 | 15.98 |
| 1968 ........ | 66.16 | 4.56 | 10.44 | 6.64 | 6.98 | 19.68 | 17.86 |
| 1969 ........ | 73.92 | 5.17 | 11.84 | 8.44 | 7.52 | 21.37 | 19.58 |
| 1970 ........ | 84.68 | 5.88 | 13.70 | 9.98 | 8.38 | 24.39 | 22.35 |
| 1971 ........ | 84.94 | 6.36 | 7.92 | 11.56 | 9.49 | 25.31 | 24.30 |
| 1972 ........ | 103.38 | 7.57 | 17.27 | 14.21 | 10.54 | 25.42 | 28.36 |
| 1973 ........ | 130.44 | 9.90 | 23.56 | 17.25 | 12.49 | 32.27 | 34.98 |
| 1974 ........ | 155.52 | 11.45 | 27.78 | 19.86 | 14.58 | 40.30 | 41.56 |
| 1975 ........ | 148.91 | 12.15 | 24.56 | 18.01 | 14.93 | 39.11 | 40.15 |
| 1976 ........ | 162.98 | 13.61 | 27.89 | 24.19 | 14.67 | 41.17 | 41.46 |
| 1977 ........ | 174.27 | 14.55 | 30.06 | 26.85 | 16.47 | 41.25 | 45.09 |
| 1978 ........ | 203.55 | 16.82 | 34.30 | 32.55 | 20.16 | 48.24 | 51.48 |
| 1979 ........ | 228.67 | 20.68 | 38.50 | 32.78 | 22.99 | 55.39 | 58.33 |
| 1980 ........ | 250.65 | 20.50 | 39.52 | 38.01 | 27.49 | 63.82 | 61.30 |
| 1981 ........ | 233.47 | 17.67 | 33.59 | 42.85 | 21.70 | 64.27 | 53.39 |
| 1982 ........ | 202.67 | 16.59 | 21.48 | 37.15 | 20.45 | 58.11 | 48.88 |
| 1983 ........ | 215.14 | 16.09 | 30.63 | 42.32 | 18.73 | 57.92 | 49.43 |
| 1984 ........ | 229.71 | 16.81 | 31.16 | 51.08 | 19.32 | 60.61 | 50.73 |

(continued)

## Appendix table 7-10. (Continued)

| Year | All Countries[2] | France | West Germany | Japan | United Kingdom | United States | Other |
|---|---|---|---|---|---|---|---|
| | Market shares (percent) | | | | | | |
| 1965 ........ | 100.00 | 7.49 | 16.47 | 7.24 | 12.22 | 28.40 | 28.18 |
| 1966 ........ | 100.00 | 7.69 | 16.35 | 8.61 | 12.78 | 27.49 | 27.09 |
| 1967 ........ | 100.00 | 7.60 | 16.22 | 8.90 | 11.32 | 28.86 | 27.10 |
| 1968 ........ | 100.00 | 6.89 | 15.78 | 10.03 | 10.55 | 29.74 | 27.00 |
| 1969 ........ | 100.00 | 7.00 | 16.02 | 11.42 | 10.[illegible]7 | 28.91 | 26.48 |
| 1970 ........ | 100.00 | 6.94 | 16.18 | 11.78 | 9.90 | 28.81 | 26.40 |
| 1971 ........ | 100.00 | 7.49 | 9.32 | 13.61 | 11.17 | 29.80 | 28.61 |
| 1972 ........ | 100.00 | 7.33 | 16.71 | 13.74 | 10.19 | 24.59 | 27.44 |
| 1973 ........ | 100.00 | 7.59 | 18.07 | 13.22 | 9.57 | 24.74 | 26.81 |
| 1974 ........ | 100.00 | 7.36 | 17.86 | 12.77 | 9.37 | 25.91 | 26.72 |
| 1975 ........ | 100.00 | 8.16 | 16.49 | 12.10 | 10.03 | 26.26 | 26.97 |
| 1976 ........ | 100.00 | 8.35 | 17.11 | 14.84 | 9.00 | 25.26 | 25.44 |
| 1977 ........ | 100.00 | 8.35 | 17.25 | 15.41 | 9.45 | 23.67 | 25.87 |
| 1978 ........ | 100.00 | 8.26 | 16.85 | 15.99 | 9.91 | 23.70 | 25.29 |
| 1979 ........ | 100.00 | 9.04 | 16.83 | 14.34 | 10.05 | 24.22 | 25.51 |
| 1980 ........ | 100.00 | 8.18 | 15.77 | 15.16 | 10.97 | 25.46 | 24.46 |
| 1981 ........ | 100.00 | 7.57 | 14.39 | 18.35 | 9.29 | 27.53 | 22.87 |
| 1982 ........ | 100.00 | 8.19 | 10.60 | 18.33 | 10.09 | 28.67 | 24.12 |
| 1983 ........ | 100.00 | 7.48 | 14.24 | 19.67 | 8.71 | 26.92 | 22.98 |
| 1984 ........ | 100.00 | 7.32 | 13.57 | 22.24 | 8.41 | 26.38 | 22.08 |

[1] Uses the DOC-3 definition of "high-technology products". See page 127 in text

[2] "All countries" includes, in addition to those shown here, Austria, Belgium, Canada, Denmark, Italy, The Netherlands, Norway, Sweden, and Switzerland.

[3] Current-dollar figures are transformed into constant terms using the GNP deflator

SOURCE: Victoria L. Hatter, "U.S. High Technology Trade and Competitiveness," Staff Report, Office of Trade and Investment Analysis, International Trade Administration, U.S. Department of Commerce, February, 1985. Office of Trade and Investment Analysis, International Trade Administration, U.S. Department of Commerce, unpublished statistics (June, 1987)

See figure 7-8.

## Appendix table 7-11. U.S. trade in high-technology[1] product groups, by region: 1978-86

| Year | Japan Exports | Japan Imports | Japan Balance | Other Developed Countries Exports | Other Developed Countries Imports | Other Developed Countries Balance | East Asian NIC's[3] Exports | East Asian NIC's[3] Imports | East Asian NIC's[3] Balance | Other Countries Exports | Other Countries Imports | Other Countries Balance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Billions of constant 1982[2] dollars | | | | | | | | | | | |
| 1978 ....... | 3.27 | 9.86 | 6.59 | 24.32 | 10.57 | 13.75 | 3.34 | 4.85 | 1.51 | 44.90 | 23.25 | 21.65 |
| 1979 ....... | 6.14 | 8.96 | - 2.82 | 26.73 | 11.56 | 15.17 | 4.64 | 5.11 | 0.48 | 50.76 | 23.84 | 26.91 |
| 1980 ....... | 6.39 | 9.14 | 2.75 | 31.49 | 13.34 | 18.15 | 5.27 | 5.47 | 0.20 | 58.56 | 27.22 | 31.34 |
| 1981 ....... | 7.16 | 11.42 | 4.26 | 31.29 | 13.68 | 17.61 | 4.59 | 5.84 | 1.25 | 59.68 | 30.16 | 29.52 |
| 1982 ....... | 6.15 | 11.25 | - 5.11 | 27.46 | 12.40 | 15.05 | 4.53 | 5.88 | 1.34 | 53.58 | 28.65 | 24.94 |
| 1983 ....... | 6.55 | 13.90 | - 7.35 | 28.50 | 12.35 | 16.15 | 5.50 | 7.89 | 2.39 | 52.43 | 31.97 | 20.45 |
| 1984 ....... | 7.77 | 20.56 | 12.79 | 29.62 | 16.96 | 12.66 | 5.92 | 10.37 | - 4.46 | 54.81 | 44.75 | 10.06 |
| 1985 ....... | 7.29 | 22.57 | - 15.27 | 30.38 | 19.06 | 11.32 | 5.62 | 9.98 | - 4.37 | 55.74 | 48.10 | 7.64 |
| 1986 ....... | 7.00 | 25.67 | - 18.67 | 33.03 | 21.05 | 11.98 | 5.76 | 11.89 | 6.13 | 57.51 | 53.64 | 3.87 |
| | Billions of dollars | | | | | | | | | | | |
| 1978 ....... | 2.36 | 7.12 | - 4.76 | 17.57 | 7.63 | 9.93 | 2.41 | 3.50 | - 1.09 | 32.43 | 16.79 | 15.63 |
| 1979 ....... | 4.82 | 7.04 | 2.22 | 21.00 | 9.08 | 11.92 | [illegible] | 4.02 | - 0.38 | 39.88 | 18.74 | 21.15 |
| 1980 ....... | 5.48 | 7.84 | - 2.36 | 26.99 | 11.44 | 15.56 | 4.51 | 4.69 | - 0.17 | 50.20 | 23.33 | 26.87 |
| 1981 ....... | 6.73 | 10.73 | - 4.00 | 29.40 | 12.85 | 16.55 | 4.32 | 5.49 | - 1.17 | 56.08 | 28.34 | 27.74 |
| 1982 ....... | 6.15 | 11.25 | - 5.11 | 27.46 | 12.40 | 15.05 | 4.53 | 5.88 | 1.34 | 53.58 | 28.65 | 24.94 |
| 1983 ....... | 6.81 | 14.44 | 7.63 | 29.60 | 12.83 | 16.77 | 5.71 | 8.19 | 2.48 | 54.45 | 33.21 | 21.24 |
| 1984 ....... | 8.38 | 22.18 | - 13.80 | 31.96 | 18.29 | 13.66 | 6.38 | 11.19 | 4.81 | 59.13 | 48.27 | 10.85 |
| 1985 ....... | 8.13 | 25.17 | - 17.03 | 33.88 | 21.26 | 12.62 | 6.26 | 11.13 | 4.87 | 62.16 | 53.64 | 8.52 |
| 1986 ....... | 8.02 | 29.42 | - 21.40 | 37.86 | 24.13 | 1[illegible].73 | 6.61 | 13.63 | 7.02 | 65.91 | 61.48 | 4.43 |

[1] U.S. Department of Commerce DOC-3 definitions.
[2] Converted to constant dollars using the GNP implicit price deflator.
[3] Newly industrialized countries in East Asia include Hong Kong, Republic of Korea, Singapore, and Taiwan

SOURCES: U.S. Department of Commerce, International Trade Administration, *U.S Trade Performance in 1985 and Outlook* (October, 1986). U.S Department of Commerce, International Trade Administration, Office of Trade and Investment Analysis, unpublished data

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## Appendix table 7-12. Exports of selected high-technology products, volume and market shares, selected countries: 1975, 1984

| Product group | United States 1975 | United States 1984 | Japan 1975 | Japan 1984 | West Germany 1975 | West Germany 1984 | France 1975 | France 1984 | United Kingdom 1975 | United Kingdom 1984 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Million[illegible]rs | | | | | | | | | |
| All high technology products .... | 23,193.5 | 65,510.0 | 10,683.7 | 55,216.6 | 14,566.[illegible] | 33,684.2 | 7,203.7 | 18,172.8 | 8,855.7 | 20,879.3 |
| Communications equipment & electronic components ...... | 3,884.2 | 14,425.0 | 4,749.5 | 29,195.4 | 3,187.5 | 6,712.3 | 1,292.7 | 3,185.1 | 1,426.9 | 3,677.9 |
| Aircraft & parts ................ | 7,119.2 | 13,540.1 | 29.6 | 143.2 | 465.3 | 4,095.0 | 865.0 | 3,181.9 | 1,625.0 | 3,943.4 |
| Office, computing, & accounting machines ......... | 2,790.9 | 14,698.9 | 1,006.7 | 9,884.7 | 1,570.1 | 3,986.7 | 731.8 | 2,264.1 | 1,027.3 | 3,836.1 |
| | Market shares (percent) | | | | | | | | | |
| All high technology products ..... | 26.3 | 26.4 | 12.1 | 22.2 | 16.5 | 13.6 | 8.2 | 7.3 | 10.0 | 8.4 |
| Communications equipment & electronic components ...... | 18.8 | 21.1 | 23.9 | 36.6 | 16.1 | 12.2 | 6.5 | 5.2 | 7.2 | 6.3 |
| Aircraft & parts ................ | 62.2 | 45.9 | 0.3 | 0.6 | 4.1 | 15.6 | 7.6 | 9.4 | 14.3 | 15.5 |
| Office, computing, & accounting machines ....... | 30.1 | 36.7 | 11.0 | 17.5 | 17.2 | 12.2 | 8.0 | 6.2 | 11.2 | 9.0 |

SOURCE: Victoria L. Hatter, U.S Department of Commerce, International Trade Administration, Office of Trade and Investment Analysis, unpublished tabulations (June, 1987)

See figure 7-9.

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## Appendix table 7-13. Direct investment positions abroad and shares of total international direct investment, major investing countries and world total, 1973-84

| Country of origin | 1973 | 1978 | 1981 | 1984 | Average annual growth 1973-78 | Average annual growth 1973-84 |
|---|---|---|---|---|---|---|
| | Billions of constant 1982 dollars[1] | | | | Percent | |
| All countries | 430.2 | 524.6 | 580.7 | 620.1 | 4.1 | 3.4 |
| Total, major investing countries | 388.8 | 474.1 | 527.1 | 532.4 | 4.0 | 2.9 |
| United States | 204.5 | 225.3 | 243.0 | 213.0 | 2.0 | 0.4 |
| United Kingdom | 54.3 | 56.9 | 69.7 | 77.6 | 0.9 | 3.3 |
| West Germany | 24.0 | 44.0 | 48.4 | 53.2 | 12.9 | 7.5 |
| Japan | 20.8 | 37.1 | 39.4 | 49.5 | 12.3 | 8.2 |
| Netherlands | 31.1 | 32.8 | 34.5 | 37.9 | 1.1 | 1.8 |
| Switzerland | 20.6 | 38.5 | 38.7 | 36.8 | 13.3 | 5.4 |
| Canada | 15.7 | 18.8 | 27.2 | 33.9 | 3.6 | 7.2 |
| France | 17.8 | 20.6 | 26.1 | 30.4 | 3.0 | 5.0 |
| Other countries | 41.4 | 50.5 | 53.6 | 87.7 | 4.1 | 7.1 |

[1] Data converted to 1982 dollars using the U.S. GNP deflator.

SOURCES: Foreign countries (1973-1981): U.S. Department of Commerce, International Trade Administration, *International Direct Investment: Global Trends and the U.S. Role* (August, 1984); foreign countries, later years derived by adding direct investment outflows reported to the IMF and published in IMF *Balance of Payments Statistics Yearbook, Part 2*, 1985; United States: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (June, 1986), p. 30

See figures 7-10, 7-11

## Appendix table 8-1. Various segments of U.S. public attentive to or interested in science and technology: 1985

| Segment of public | Attentive public | Interested public | Remaining public | N |
|---|---|---|---|---|
| | Percent | | | |
| Total public | 21 | 26 | 53 | 2,005 |
| Age: | | | | |
| 18-24 | 21 | 23 | 56 | 326 |
| 25-34 | 19 | 30 | 51 | 474 |
| 35-44 | 22 | 24 | 53 | 370 |
| 45-64 | 22 | 27 | 51 | 520 |
| 65 + | 19 | 22 | 59 | 315 |
| Gender: | | | | |
| Female | 17 | 24 | 59 | 1,054 |
| Male | 25 | 27 | 47 | 950 |
| Education: | | | | |
| Less than high school | 12 | 21 | 67 | 507 |
| High school graduate | 21 | 27 | 52 | 1,006 |
| AA Degree | 29 | 25 | 46 | 137 |
| BA Degree | 33 | 28 | 39 | 229 |
| Graduate degree | 28 | 28 | 44 | 121 |

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-1 in text.

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## Appendix table 8-2. Reported understanding of various aspects of science and technology: 1985

| Segment of public | Scientific study | DNA | Molecule | Computer software | Radiation | GNP | How a telephone works | N |
|---|---|---|---|---|---|---|---|---|
| | Percent claiming clear understanding | | | | | | | |
| Total public | 29 | 14 | 27 | 20 | 29 | 23 | 18 | 2,005 |
| Age: | | | | | | | | |
| 18-24 | 34 | 17 | 30 | 20 | 27 | 23 | 15 | 326 |
| 25-34 | 35 | 25 | 36 | 26 | 28 | 25 | 20 | 474 |
| 35-44 | 32 | 17 | 33 | 25 | 35 | 26 | 19 | 370 |
| 45-64 | 30 | 5 | 21 | 20 | 27 | 22 | 19 | 520 |
| 65 + | 13 | 6 | 16 | 7 | 26 | 20 | 15 | 315 |
| Gender: | | | | | | | | |
| Female | 27 | 13 | 22 | 16 | 24 | 15 | 12 | 1,054 |
| Male | 32 | 16 | 33 | 25 | 33 | 32 | 24 | 950 |
| Education: | | | | | | | | |
| Less than high school | 13 | 4 | 8 | 2 | 21 | 8 | 17 | 507 |
| High school graduate | 27 | 12 | 24 | 20 | 26 | 20 | 16 | 1,006 |
| AA degree | 30 | 16 | 41 | 28 | 29 | 30 | 20 | 137 |
| BA degree | 57 | 31 | 58 | 40 | 44 | 47 | 25 | 229 |
| Graduate degree | 61 | 39 | 62 | 55 | 55 | 60 | 26 | 121 |

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-2 in text.

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## Appendix table 8-3. Actual understanding of various aspects of science and technology: 1985

| Segment of public | Molecule | Scientific study | How a telephone works | N |
|---|---|---|---|---|
| | — Percent responding correctly — | | | |
| Total public | 10 | 13 | 8 | 2.005 |
| Age: | | | | |
| 18-24 | 13 | 16 | 6 | 326 |
| 25-34 | 14 | 14 | 11 | 474 |
| 35-44 | 13 | 17 | 10 | 370 |
| 45-64 | 5 | 11 | 7 | 520 |
| 65 + | 4 | 4 | 3 | 315 |
| Gender: | | | | |
| Female | 8 | 13 | 2 | 1,054 |
| Male | 12 | 13 | 14 | 950 |
| Education: | | | | |
| Less than high school | 2 | 2 | 2 | 507 |
| High school graduate | 8 | 13 | 7 | 1,006 |
| AA degree | 15 | 16 | 11 | 137 |
| BA degree | 22 | 22 | 16 | 229 |
| Graduate degree | 27 | 31 | 20 | 121 |

"In your own words. could you tell me what a molecule is?"

[1] Question was asked only of those who previously had stated they had either a "clear understanding" or a "general sense" of this aspect. Percentages are based on total sample. Responses were coded at the Public Opinion Laboratory, with tests of intercoder reliability.

SOURCE: Jon D. Miller *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-3 in text. Science & Engineering Indicators—1987

## Appendix table 8-4. Reported understanding of various aspects of science and technology by Japanese: 1987

| Aspect | Understand | Certain extent | Heard before | Don't understand |
|---|---|---|---|---|
| | — Percent — | | | |
| GNP | 27 | 19 | 28 | 27 |
| Computer software | 21 | 19 | 31 | 29 |
| Optical fibers | 21 | 20 | 36 | 23 |
| IC,LSI | 19 | 16 | 31 | 34 |
| Data base | 13 | 12 | 29 | 47 |
| DNA | 8 | 7 | 19 | 67 |
| N = 2,334 | | | | |

"To what degree do you understand the following words?"

SOURCE: Office of the Prime Minister of Japan, Public Relations Office. *Public Opinion Survey on Science, Technology, and Society* (1988)

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## Appendix table 8-5. Public[1] using various information sources: 1985

| Segment of public | Watch science television | Visit public library | Visit zoo or aquarium | Visit science museum[2] | Visit art museum | Read science magazines | N |
|---|---|---|---|---|---|---|---|
| | Percent | | | | | | |
| Total public | 71 | 67 | 48 | 38 | 31 | 16 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 60 | 79 | 57 | 46 | 41 | 12 | 326 |
| 25-34 | 71 | 77 | 65 | 49 | 36 | 19 | 474 |
| 35-44 | 76 | 73 | 56 | 45 | 36 | 20 | 370 |
| 45-64 | 71 | 57 | 37 | 29 | 24 | 15 | 520 |
| 65 + | 74 | 51 | 22 | 19 | 21 | 12 | 315 |
| Gender: | | | | | | | |
| Female | 68 | 70 | 49 | 34 | 33 | 15 | 1,054 |
| Male | 73 | 64 | 48 | 39 | 30 | 18 | 950 |
| Education: | | | | | | | |
| Less than high school | 61 | 46 | 32 | 18 | 12 | 7 | 507 |
| High school graduate | 71 | 70 | 48 | 37 | 30 | 15 | 1,006 |
| AA Degree | 78 | 82 | 67 | 54 | 46 | 22 | 137 |
| BA Degree | 80 | 85 | 67 | 62 | 55 | 27 | 229 |
| Graduate degree | 84 | 88 | 68 | 62 | 62 | 32 | 121 |

[1] In the case of science magazines and science television this is the percent who use them at least occasionally. In other cases, it is those who had used the source at least once in the past year.

[2] Includes visits to a "Science or technology museum" or a "Natural history museum"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-5 in text.

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## Appendix table 8-6. Weekly science and health sections in U.S. daily newspapers: 1977-86

| Year[1] | Science[2] | Health[3] |
|---|---|---|
| 1977 | 0 | 0 |
| 1978 | 1 | 0 |
| 1979 | 1 | 0 |
| 1980 | 1 | 0 |
| 1981 | 4 | 1 |
| 1982 | 7 | 1 |
| 1983 | 16 | 2 |
| 1984 | 27 | 4 |
| 1985 | 45 | 15 |
| 1986 | 61 | 20 |

[1] As of September of each year.

[2] Science sections including health and fitness. Groups of newspapers with the same science editor were counted as one newspaper. Multiple weekly columns were counted separately.

[3] Health and fitness exclusively.

SOURCE: Scientists' Institute for Public Information, *SIPI Scope*, vol.14, No.4, Autumn 1986

See figure 8-1.

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## Appendix table 8-7. Computer use at home and at work: 1985

| Segment of public | At home and work | At work | At home | No use | N |
|---|---|---|---|---|---|
| | Percent | | | | |
| Total public | 5 | 19 | 7 | 69 | 2,005 |
| Age: | | | | | |
| 18-24 | 3 | 24 | 7 | 66 | 326 |
| 25-34 | 8 | 26 | 7 | 60 | 474 |
| 35-44 | 9 | 22 | 10 | 59 | 370 |
| 45-64 | 3 | 18 | 6 | 72 | 520 |
| 65 + | 0 | 3 | 3 | 94 | 315 |
| Gender: | | | | | |
| Female | 4 | 18 | 6 | 72 | 1,054 |
| Male | 6 | 21 | 7 | 66 | 950 |
| Education: | | | | | |
| Less than high school | 0 | 7 | 5 | 89 | 507 |
| High school graduate | 3 | 20 | 6 | 71 | 1,006 |
| AA Degree | 9 | 27 | 13 | 51 | 137 |
| BA Degree | 12 | 33 | 7 | 48 | 229 |
| Graduate degree | 17 | 31 | 12 | 40 | 121 |

Note: Cases which indicated that "Entertainment" was primary use of computer were placed in "Does not use" category.

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology. 1985* (1988)

See table 8-6 in text.



## Appendix table 8-8. Public assessment of beneficial versus harmful results of scientific research: 1985

| Segment of public | Benefits substan'ly greater | Benefits slightly greater | Benefits equal harms[1] | Harms slightly greater | Harms substan'ly greater | Don't know | N |
|---|---|---|---|---|---|---|---|
| | Percent | | | | | | |
| Total public | 44 | 24 | 4 | 13 | 6 | 9 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 37 | 29 | 2 | 22 | 5 | 5 | 326 |
| 25-34 | 46 | 26 | 2 | 16 | 5 | 5 | 474 |
| 35-44 | 54 | 21 | 6 | 10 | 4 | 5 | 370 |
| 45-64 | 46 | 20 | 4 | 10 | 8 | 12 | 520 |
| 65 + | 31 | 23 | 7 | 9 | 9 | 21 | 315 |
| Gender: | | | | | | | |
| Female | 40 | 25 | 4 | 14 | 6 | 11 | 1,054 |
| Male | 48 | 22 | 4 | 13 | 5 | 7 | 950 |
| Education: | | | | | | | |
| Less than high school | 20 | 21 | 7 | 19 | 13 | 20 | 507 |
| High school graduate | 46 | 25 | 4 | 13 | 4 | 8 | 1,006 |
| AA Degree | 54 | 26 | 3 | 7 | 5 | 5 | 137 |
| BA Degree | 64 | 23 | 1 | 7 | 3 | 2 | 229 |
| Graduate degree | 71 | 20 | 2 | 3 | 1 | 3 | 121 |
| Attentiveness: | | | | | | | |
| Attentives | 55 | 23 | 3 | 10 | 4 | 5 | 417 |
| Interested | 48 | 24 | 5 | 11 | 4 | 8 | 517 |
| Remaining | 37 | 26 | 5 | 15 | 7 | 10 | 1,071 |

"People have frequently noted that scientific research has produced both beneficial and harmful consequences. Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or that the harmful results of scientific research have outweighed its benefits?"

[1] Volunteered by respondent.

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology. 1985* (1988)

See table 8-7 in text.

## Appendix table 8-9. Benefits and harms from scientific advance, for various countries: 1981-83

| Country | Will help | Will harm | Both | No answer/ Don't know |
|---|---|---|---|---|
| | Percent | | | |
| Japan | 23.4 | 9.6 | 57.4 | 9.6 |
| United Kingdom | 48.3 | 21.8 | 25.9 | 4.1 |
| France | 36.9 | 21.3 | 36.2 | 5.7 |
| West Germany | 32.4 | 21.1 | 40.0 | 6.5 |
| Italy | 39.4 | 20.2 | 35.9 | 4.5 |
| United States | 54.3 | 19.0 | 21.5 | 5.2 |
| Canada | 44.7 | 22.3 | 29.4 | 3.5 |
| Lebanon | 52.2 | 9.0 | 36.7 | 2.1 |
| Kuwait | 69.1 | 4.2 | 25.5 | 1.2 |
| Australia | 45.0 | 26.4 | 25.2 | 3.3 |
| Netherlands | 21.9 | 36.4 | 33.6 | 8.1 |
| Denmark | 30.9 | 20.6 | 42.3 | 6.2 |
| Belgium | 25.1 | 17.5 | 46.4 | 11.1 |
| Spain | 44.0 | 18.0 | 31.0 | 7.0 |
| Ireland | 37.8 | 27.5 | 26.7 | 8.0 |
| Ulster | 37.0 | 22.0 | 35.0 | 6.0 |
| Sweden | 35.0 | 21.0 | 40.0 | 4.0 |

"In the long run, do you think the scientific advances we're making will help or harm mankind?"

Note: Data are from 1981, except for Canada (1982) and Kuwait, Lebanon, and Australia (1983)

SOURCE. Internationales Institut fur Empirische Sozialokonomie, Stadtbergen, FRG, unpublished tabulations

See figure O-33 in Overview.

## Appendix table 8-10. Public expectations concerning future outcomes, by attentiveness: 1985

| Outcome | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| A cure for the common forms of cancer: | | | | |
| Very likely | 55 | 63 | 57 | 51 |
| Possible | 37 | 31 | 35 | 40 |
| Not at all likely | 6 | 4 | 7 | 3 |
| Don't know | 2 | 2 | 1 | 3 |
| A war in space: | | | | |
| Very likely | 12 | 13 | 11 | 13 |
| Possible | 34 | 36 | 28 | 36 |
| Not at all likely | 50 | 50 | 57 | 47 |
| Don't know | 4 | 2 | 3 | 5 |
| A safe method for the long-term storage or disposal of waste products from nuclear power plants: | | | | |
| Very likely | 36 | 41 | 40 | 33 |
| Possible | 42 | 37 | 36 | 46 |
| Not at all likely | 18 | 20 | 19 | 17 |
| Don't know | 4 | 2 | 4 | 5 |
| The accidental release of a genetically engineered microbe into the environment: | | | | |
| Very likely | 17 | 20 | 15 | 18 |
| Possible | 50 | 56 | 49 | 48 |
| Not at all likely | 20 | 17 | 25 | 19 |
| Don't know | 13 | 7 | 11 | 16 |
| The placement of a scientific or mining colony on the moon: | | | | |
| Very likely | 32 | 37 | 32 | 30 |
| Possible | 39 | 40 | 42 | 38 |
| Not at all likely | 25 | 20 | 23 | 28 |
| Don't know | 4 | 3 | 3 | 5 |
| Another nuclear power plant accident like Three Mile Island: | | | | |
| Very likely | 46 | 47 | 44 | 47 |
| Possible | 41 | 45 | 44 | 38 |
| Not at all likely | 9 | 6 | 9 | 11 |
| Don't know | 4 | 3 | 3 | 5 |
| The accidental release in the United States of a toxic chemical that will result in numerous deaths: | | | | |
| Very likely | 42 | 44 | 41 | 42 |
| Possible | 42 | 45 | 42 | 42 |
| Not at all likely | 12 | 9 | 15 | 12 |
| Don't know | 4 | 2 | 2 | 5 |
| The development of genetically engineered bacteria to eat or destroy toxic chemicals: | | | | |
| Very likely | 32 | 41 | 37 | 26 |
| Possible | 43 | 42 | 38 | 47 |
| Not at all likely | 17 | 13 | 18 | 17 |
| Don't know | 8 | 5 | 8 | 10 |
| The landing of a manned mission on Mars: | | | | |
| Very likely | 27 | 32 | 28 | 24 |
| Possible | 41 | 41 | 41 | 41 |
| Not at all likely | 29 | 25 | 29 | 30 |
| Don't know | 4 | 3 | 3 | 4 |
| A cure for the disease AIDS: | | | | |
| Very likely | 49 | 58 | 54 | 44 |
| Possible | 38 | 31 | 34 | 42 |
| Not at all likely | 9 | 9 | 10 | 9 |
| Don't know | 4 | 2 | 3 | 5 |

"Do you think that it is very likely, possible but not too likely, or not at all likely that this result will occur in the next 25 years?"

SOURCE: Jon D Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-9 in text

## Appendix table 8-11. Japanese public expectations concerning future outcomes: 1987

| Outcome | Most probably will occur | Possibility is low | Will not occur | Don't know |
|---|---|---|---|---|
| | Percent | | | |
| Progress in curing cancer | 74 | 17 | 4 | 5 |
| Automatic translation devices for international travelers | 62 | 17 | 7 | 13 |
| Progress in curing AIDS | 58 | 22 | 7 | 12 |
| Earthquake prediction | 52 | 31 | 9 | 8 |
| Safe processing method for atomic waste | 44 | 29 | 12 | 14 |
| Progress in curing senility | 34 | 37 | 17 | 11 |
| Landing people on Mars | 33 | 29 | 21 | 17 |
| Living in space stations | 23 | 32 | 30 | 15 |
| Cities in the ocean | 18 | 33 | 35 | 15 |
| N = 2,334 | | | | |

"Do you think that the following things will take place in the next 25 years?"

SOURCE: Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (1988)

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## Appendix table 8-12. Public indicating "a great deal of confidence" in the people running selected institutions: 1973-86

| Institution | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1980 | 1982 | 1983 | 1984 | 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent | | | | | | | | | | |
| Medicine | 54 | 60 | 50 | 54 | 51 | 46 | 52 | 46 | 51 | 50 | 46 |
| Scientific community | 37 | 45 | 38 | 43 | 41 | 36 | 41 | 38 | 41 | 44 | 39 |
| Education | 37 | 49 | 31 | 37 | 41 | 28 | 30 | 33 | 29 | 28 | 28 |
| Organized religion | 35 | 44 | 24 | 30 | 40 | 31 | 35 | 32 | 28 | 31 | 25 |
| Military | 32 | 40 | 35 | 39 | 36 | 29 | 28 | 31 | 29 | 36 | 31 |
| Major companies | 29 | 31 | 19 | 22 | 27 | 22 | 27 | 23 | 24 | 30 | 24 |
| Press | 23 | 26 | 24 | 28 | 25 | 20 | 22 | 18 | 13 | 17 | 18 |
| TV | 19 | 23 | 18 | 19 | 17 | 14 | 16 | 14 | 12 | 14 | 15 |
| Organized labor | 15 | 18 | 10 | 12 | 15 | 11 | 15 | 12 | 8 | 8 | 8 |
| Executive branch of the federal government | 29 | 14 | 13 | 13 | 28 | 12 | 12 | 19 | 13 | 18 | 21 |
| Congress | 23 | 17 | 13 | 14 | 19 | 13 | 9 | 13 | 10 | 12 | 16 |
| U.S. Supreme Court | 31 | 33 | 31 | 35 | 35 | 28 | 25 | 30 | 28 | 33 | 30 |
| Banks and financial institutions | NA | NA | 32 | 39 | 42 | 33 | 32 | 25 | 24 | 31 | 21 |
| N = | 1,504 | 1,484 | 1,490 | 1,499 | 1,530 | 1,532 | 1,468 | 1,506 | 1,599 | 989 | 1,470 |

"I am going to name some institutions in this country. As far as the *people running* these institutions are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?"

SOURCES: James A. Davis, Tom W. Smith, *General Social Surveys Cumulative Codebook, 1972-1985*, Roper Center, pp. 166-169; unpublished 1986 data provided by Tom W. Smith

See figure 8-2.

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## Appendix table 8-13. Public image of scientists: 1985

| Segment of public | Percent agreeing that scientists | | N |
|---|---|---|---|
| | Work for good of humanity | Have power that is dangerous | |
| Total public | 80 | 55 | 2.005 |
| Age: | | | |
| 18-24 | 83 | 55 | 362 |
| 25-34 | 79 | 52 | 474 |
| 35-44 | 78 | 46 | 370 |
| 45-64 | 80 | 55 | 520 |
| 65 + | 81 | 66 | 315 |
| Gender: | | | |
| Female | 81 | 58 | 1,054 |
| Male | 78 | 52 | 950 |
| Education: | | | |
| Less than high school | 81 | 69 | 507 |
| High school graduate | 80 | 56 | 1.006 |
| AA Degree | 82 | 42 | 137 |
| BA Degree | 80 | 36 | 229 |
| Graduate degree | 73 | 34 | 121 |

"For each statement. tell me if you generally agree or generally disagree."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-12 in text.

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## Appendix table 8-14. Public acceptance of scientific conclusions: 1985

| Segment of public | A | B | C | D | E | F | N |
|---|---|---|---|---|---|---|---|
| | Percent | | | | | | |
| Total public | 44 | 46 | 53 | 95 | 45 | 79 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 41 | 42 | 50 | 97 | 51 | 79 | 326 |
| 25-34 | 48 | 42 | 56 | 97 | 51 | 81 | 474 |
| 35-44 | 50 | 40 | 53 | 93 | 51 | 78 | 370 |
| 45-64 | 43 | 52 | 52 | 94 | 40 | 78 | 520 |
| 65 + | 35 | 53 | 50 | 93 | 34 | 82 | 315 |
| Gender: | | | | | | | |
| Female | 33 | 44 | 54 | 94 | 41 | 77 | 1,054 |
| Male | 55 | 48 | 51 | 96 | 50 | 82 | 950 |
| Education: | | | | | | | |
| Less than high school | 29 | 46 | 36 | 92 | 39 | 72 | 507 |
| High school graduate | 44 | 44 | 55 | 95 | 40 | 79 | 1,006 |
| AA Degree | 50 | 49 | 63 | 98 | 49 | 82 | 137 |
| BA Degree | 63 | 52 | 67 | 97 | 64 | 88 | 229 |
| Graduate degree | 64 | 48 | 70 | 98 | 72 | 92 | 121 |

Note: A – Disagree that "Rocket launchings and other space activities have caused changes in our weather."
B = Disagree that "It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations."
C – Disagree that "Some numbers are especially lucky for some people."
D = Agree that "Smoking causes serious health problems."
E – Agree that "Human beings as we know them today developed from earlier species of animals."
F – Agree that "The continents on which we live have been moving their location for millions of years and will continue to move in the future."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-13 in text

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## Appendix table 8-15. Public views of the limits of science: 1985

| Segment of public | A | B | C | D | N |
|---|---|---|---|---|---|
| | Percent | | | | |
| Total public | 59 | 75 | 8 | 8 | 2,005 |
| Age: | | | | | |
| 18-24 | 66 | 73 | 11 | 10 | 326 |
| 25-34 | 57 | 77 | 6 | 6 | 474 |
| 35-44 | 53 | 75 | 6 | 8 | 370 |
| 45-64 | 58 | 76 | 6 | 8 | 520 |
| 65 + | 62 | 73 | 12 | 11 | 315 |
| Gender: | | | | | |
| Female | 59 | 74 | 10 | 9 | 1,054 |
| Male | 59 | 76 | 6 | 7 | 950 |
| Education: | | | | | |
| Less than high school | 67 | 76 | 17 | 14 | 507 |
| High school graduate | 59 | 74 | 6 | 8 | 1,006 |
| AA Degree | 57 | 74 | 4 | 4 | 137 |
| BA Degree | 49 | 78 | 2 | 4 | 229 |
| Graduate degree | 45 | 73 | 5 | 1 | 121 |

Note: A = Agree that "Scientists will never be able to understand the working of the human mind as well as they understand the physical world."

B = Agree that "There are some good ways of treating sickness that medical science does not recognize."

C = Responded 'Yes' to "Do you sometimes decide to do or not do something because your astrological signs for the day are favorable or unfavorable?"

D = Stated that "Astrology is very scientific."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-15 in text. Science & Engineering Indicators—1987

## Appendix table 8-16. Public considering U.S. ahead of other countries in science and technology, by attentiveness: 1985

| Area and country | Total public | Attentive public | Interested public | Remaining public |
|---|---|---|---|---|
| | Percent | | | |
| Basic scientific achievements: | | | | |
| West Germany | 58 | 66 | 61 | 54 |
| France | 75 | 82 | 77 | 71 |
| Japan | 36 | 41 | 36 | 34 |
| Great Britain | 70 | 78 | 74 | 66 |
| Soviet Union | 43 | 55 | 43 | 39 |
| Military technology: | | | | |
| West Germany | 70 | 75 | 75 | 66 |
| France | 80 | 84 | 86 | 77 |
| Japan | 73 | 80 | 76 | 69 |
| Great Britain | 76 | 83 | 79 | 73 |
| Soviet Union | 33 | 41 | 34 | 29 |
| Civilian or industrial technology: | | | | |
| West Germany | 49 | 47 | 50 | 49 |
| France | 73 | 77 | 79 | 69 |
| Japan | 11 | 10 | 12 | 12 |
| Great Britain | 69 | 75 | 75 | 64 |
| Soviet Union | 75 | 83 | 77 | 71 |
| N = | 2,005 | 417 | 517 | 1,071 |

"In terms of basic scientific achievements, would you say that the United States is ahead of West Germany, behind West Germany or at about the same level?"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-16 in text. Science & Engineering Indicators—1987

## Appendix table 8-17. Japanese public's ranking of various countries on various aspects of scien… and technology: 1987

| Country | Basic science and technology | Industrial technology | Technology related to everyday living |
|---|---|---|---|
| | Average ranking | | |
| United States | 1.6 | 1.8 | 1.8 |
| Japan | 2.8 | 2.0 | 2.3 |
| West Germany | 3.7 | 3.7 | 3.8 |
| U.S.S.R. | 3.4 | 4.0 | 4.6 |
| United Kingdom | 4.6 | 4.5 | 4.1 |
| France | 5.1 | 4.9 | 4.4 |
| N = 2,334 | | | |

"For each of the areas listed below please rank the following countries according to their degree of progress"

SOURCE: Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (1988)

See table 8-17 in text. Science & Engineering Indicators—1987

## Appendix table 8-18 Public support for basic scientific research: 1985

| Segment of public | Strongly agree | Agree | Don't know | Disagree | Strongly disagree | N |
|---|---|---|---|---|---|---|
| | Percent | | | | | |
| Total public | 9 | 70 | 5 | 15 | 1 | 2,005 |
| Age: | | | | | | |
| 18-24 | 14 | 65 | 5 | 15 | 1 | 326 |
| 25-34 | 14 | 71 | 2 | 12 | 1 | 474 |
| 35-44 | 9 | 72 | 5 | 14 | 1 | 370 |
| 45-64 | 5 | 73 | 5 | 17 | 0 | 520 |
| 65 + | 5 | 65 | 10 | 19 | 0 | 315 |
| Gender: | | | | | | |
| Female | 7 | 68 | 8 | 16 | 1 | 1,054 |
| Male | 11 | 71 | 2 | 15 | 1 | 950 |
| Education: | | | | | | |
| Less than high school | 5 | 65 | 9 | 20 | 0 | 507 |
| High school graduate | 7 | 71 | 5 | 16 | 1 | 1,006 |
| AA degree | 9 | 78 | 2 | 11 | 0 | 137 |
| BA degree | 19 | 68 | 2 | 10 | 1 | 229 |
| Graduate degree | 19 | 70 | 2 | 8 | 0 | 121 |

"Even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Federal Government."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-18 in text. Science & Engineering Indicators—1987

## Appendix table 8-19. Public willingness to restrain scientific studies: 1979-85

| Subject | 1979 | 1983 | 1985 |
|---|---|---|---|
| | — Percent willing to prohibit — | | |
| Studies that might enable most people in society to live to be 100 or more | 29 | 32 | 26 |
| Studies that could allow parents to select the sex of their child | NA | 62 | NA |
| Studies that might allow scientists to create new forms of life | 65 | NA | NA |
| Studies that might allow scientists to create new forms of plant and animal life | NA | 46 | 42 |
| Studies that might lead to precise weather control and modification | 28 | NA | 36 |
| Studies that might discover intelligent beings in outer space | 36 | 38 | 29 |
| Studies that cause pain or injury to animals like dogs and chimpanzees, but which produce new information about human disease or health problems | NA | NA | 30 |
| Studies that are designed to create new biological or chemical weapons | NA | NA | 66 |
| N = | 1,635 | 1,630 | 2,005 |

"For each study, please tell me whether you think scientists should or should not be allowed to conduct that kind of research. If you don't care one way or the other, just give me that answer."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-19 in text

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## Appendix table 8-20. Public assessment of three policy areas, by demographic group: 1985

| Segment of public | Space exploration | | | | | | |
|---|---|---|---|---|---|---|---|
| | Benefits substantially exceed costs | Benefits only slightly exceed costs | Benefits & costs about equal (volunteered by respondent) | Costs only slightly exceed benefits | Costs substantially exceed benefits | Don't know | N |
| | Percent | | | | | | |
| Total public | 26 | 27 | 2 | 15 | 24 | 5 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 24 | 30 | 1 | 19 | 22 | 4 | 326 |
| 25-34 | 29 | 27 | 3 | 16 | 22 | 4 | 474 |
| 35-44 | 28 | 31 | 1 | 12 | 25 | 3 | 370 |
| 45-64 | 25 | 24 | 3 | 16 | 26 | 5 | 520 |
| 65 + | 23 | 25 | 4 | 14 | 26 | 9 | 315 |
| Gender: | | | | | | | |
| Female | 20 | 24 | 3 | 18 | 30 | 6 | 1,054 |
| Male | 33 | 31 | 2 | 12 | 18 | 4 | 950 |
| Education: | | | | | | | |
| Less than high school | 20 | 25 | 3 | 17 | 26 | 8 | 507 |
| High school graduate | 26 | 27 | 2 | 16 | 26 | 4 | 1,006 |
| AA Degree | 26 | 32 | 2 | 14 | 25 | 1 | 137 |
| BA Degree | 35 | 29 | 2 | 13 | 17 | 5 | 229 |
| Graduate Degree | 38 | 25 | 3 | 15 | 17 | 3 | 121 |

(Continued)

**Appendix table 8-20. (Continued)**

| | Genetic engineering research | | | | | | |
|---|---|---|---|---|---|---|---|
| | Benefits are substantially greater than risks | Benefits are only slightly greater than risks | Benefits & risks about equal (volunteered by respondent) | Risks are only slightly greater than benefits | Risks are substantially greater than benefits | Don't know | N |
| | Percent | | | | | | |
| Total public | 23 | 27 | 2 | 14 | 24 | 11 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 24 | 29 | 2 | 22 | 17 | 6 | 326 |
| 25–34 | 27 | 27 | 2 | 12 | 27 | 6 | 474 |
| 35-44 | 23 | 24 | 2 | 15 | 26 | 10 | 370 |
| 45-64 | 20 | 28 | 2 | 14 | 23 | 13 | 520 |
| 65 + | 17 | 23 | 1 | 9 | 29 | 21 | 315 |
| Gender: | | | | | | | |
| Female | 19 | 25 | 2 | 16 | 27 | 12 | 1,054 |
| Male | 26 | 28 | 2 | 13 | 22 | 9 | 950 |
| Education: | | | | | | | |
| Less than high school | 19 | 29 | 1 | 13 | 23 | 15 | 507 |
| High school graduate | 20 | 24 | 2 | 14 | 27 | 12 | 1,006 |
| AA Degree | 25 | 24 | 0 | 21 | 25 | 5 | 137 |
| BA Degree | 29 | 29 | 2 | 16 | 19 | 5 | 229 |
| Graduate Degree | 36 | 30 | 2 | 10 | 16 | 6 | 121 |

| | Nuclear power | | | | | | |
|---|---|---|---|---|---|---|---|
| | Benefits are substantially greater than risks | Benefits are only slightly greater than risks | Benefits & risks about equal (volunteered by respondent) | Risks are only slightly greater than benefits | Risks are substantially greater than benefits | Don't know | N |
| | Percent | | | | | | |
| Total public | 27 | 22 | 1 | 14 | 31 | 5 | 2,005 |
| Age: | | | | | | | |
| 18-24 | 18 | 23 | 1 | 17 | 39 | 3 | 326 |
| 25-34 | 22 | 20 | 1 | 16 | 38 | 4 | 474 |
| 35-44 | 27 | 24 | 2 | 17 | 27 | 3 | 370 |
| 45-64 | 30 | 24 | 2 | 11 | 29 | 4 | 520 |
| 65 + | 39 | 20 | 1 | 11 | 19 | 11 | 315 |
| Gender: | | | | | | | |
| Female | 18 | 22 | 2 | 17 | 35 | 6 | 1,054 |
| Male | 37 | 23 | 1 | 10 | 26 | 3 | 950 |
| Education: | | | | | | | |
| Less than high school | 28 | 24 | 1 | 15 | 25 | 7 | 507 |
| High school graduate | 26 | 22 | 2 | 13 | 33 | 4 | 1,006 |
| AA Degree | 31 | 20 | 0 | 15 | 31 | 3 | 137 |
| BA Degree | 28 | 20 | 1 | 13 | 36 | 3 | 229 |
| Graduate Degree | 27 | 23 | 1 | 17 | 31 | 2 | 121 |

"In your opinion, have the costs of space exploration exceeded its benefits, or have the benefits of space exploration exceeded its costs?"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-21 in text.

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## Appendix table 8-21. Public reactions to Shuttle Challenger accident: February 1986 and June 1986

| Question and response | February | June |
|---|---|---|
| | — Percent — | |
| "Generally speaking, would you say that this accident has been a major setback for the space program, a minor setback, or not really a setback at all?" | | |
| Major | 37 | 66 |
| Minor | 45 | 26 |
| No setback | 17 | 7 |
| Don't know | 2 | 1 |
| "If additional funds are needed to modify the shuttle program or to get it back on schedule, would you personally support increased Federal funds for the shuttle program, oppose additional funds, or would it make no difference to you?" | | |
| Support | 50 | 49 |
| Oppose | 22 | 23 |
| No difference | 26 | 26 |
| No answer | 3 | 2 |
| "The accident reflects a basic design error or flaw in the shuttle. Do you strongly agree, agree, disagree, or strongly disagree.?" | | |
| Strongly agree | 8 | 17 |
| Agree | 42 | 62 |
| Disagree | 40 | 18 |
| Strongly disagree | 6 | 2 |
| Don't know | 5 | 2 |
| "The space shuttle is such a complex machine that accidents will continue to occur from time to time." | | |
| Strongly agree | 8 | 7 |
| Agree | 75 | 76 |
| Disagree | 15 | 16 |
| Strongly disagree | 1 | 1 |
| Don't know | 1 | 1 |
| "The space program should reduce the number of manned shuttle flights and rely more on unmanned vehicles." | | |
| Strongly agree | 4 | 4 |
| Agree | 27 | 39 |
| Disagree | 55 | 49 |
| Strongly disagree | 10 | 4 |
| Don't know | 5 | 4 |
| "The space shuttle is still an outstanding example of American technology." | | |
| Strongly agree | 32 | 24 |
| Agree | 65 | 73 |
| Disagree | 2 | 3 |
| Strongly disagree | 0 | 0 |
| Don't know | 1 | 1 |
| "Do you think that manned shuttle flights will start again?" | | |
| Yes | 98 | 98 |
| No | 1 | 1 |
| Don't know | 1 | 1 |

N = 1,111 (the same set of respondents in February and in June)

SOURCE: Jon D. Miller, *The Impact of the Challenger Accident on Public Attitudes toward the Space Program*, Report to the National Science Foundation (January, 1987)

See table 8-22 in text. Science & Engineering Indicators—1987

# Appendix II
# Contributors and Reviewers

# Contributors and Reviewers

The following persons contributed to this report, by reviewing chapters or sections, by providing data, or by otherwise assisting in its preparation. Their help is greatly appreciated.

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