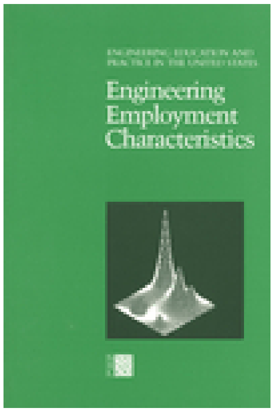

Engineering Employment Characteristics

Panel on Engineering Employment Characteristics, Committee on the Education and Utilization of the Engineer, National Research Council

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Engineering Education and Practice in the United States

Engineering Employment Characteristics

Panel on Engineering Employment Characteristics
Committee on the Education and Utilization of the Engineer
Commission on Engineering and Technical Systems
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

This panel report was prepared as part of the overall study of engineering education and practice in the United States that was conducted under the guidance of the National Research Council's Committee on the Education and Utilization of the Engineer. Many of the findings and recommendations of this report were included in the summary report of the committee,* but it was possible to address the various topics in more detail here.

The Panel on Engineering Employment Characteristics was charged with developing an understanding of the employment patterns of engineers, technologists, and technicians—who they are, where they work, and what they do—and of how those patterns have changed or are likely to change with time. To the extent possible, we have responded to this charge in statistical terms derived from analyses of data from standard sources. Where subjective assessments were required, we relied in part on the results of an informal survey conducted by the panel. Whatever the sources of the raw information, however, this report reflects the broad experience and seasoned judgment of the members of the panel, and I should like to thank them for their contributions.

FRED W. GARRY

CHAIRMAN

* *Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future* (Washington, D.C.: National Academy Press, 1985).

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Executive Summary

The Panel on Engineering Employment Characteristics prepared its report as a part of the overall effort of the National Research Council's Committee on the Education and Utilization of the Engineer. Following is a summary of the major points from this report.

The Engineering Work Force Data on the makeup of the engineering community are collected on a nonuniform basis with resulting inconsistencies. Conclusions reached from the data in this report, therefore, are best viewed in terms of trends rather than in terms of absolute numbers.

Between 1960 and 1982, the number of engineers in the United States almost doubled, to more than 1.5 million. Engineers made up only 1.4 percent of the U.S. work force in 1980. About 90 percent of U.S. engineers are employed in engineering or scientific jobs and work essentially in their degree fields.

About 75 percent of employed engineers work in business and industry. Federal agencies and programs account directly or through contractors for the employment of 300,000 to 500,000 engineers (on the order of 20 percent to 33 percent of the total), some 100,000 (about 7 percent) of them being employed directly by the federal government. Most engineers work on development- and production-related tasks and in management. Less than 5 percent of engineers are engaged in research and less than 1 percent in basic research. Only 2.3 percent of engineers work as teachers, compared to 15.7 percent for all scientists.

The primary tasks of doctoral engineers are research (24 percent) and teaching (18.6 percent). An increasing percentage of doctoral engineers are entering development and management. The absolute numbers of doctoral engineers engaged in teaching increased between 1973 and 1981, but the percentage in teaching declined from 24.6 percent to 18.6 percent.

Engineering is a stable career: unemployment exceeded 2 percent in only 3 years of the 20-year period from 1963 to 1982; average retirement age is about 62. Engineers are the highest paid of non-self-employed professionals.

Women and Minorities in Engineering The representation of women and minorities in engineering is as follows: women in 1983 constituted 5.8 percent of the engineering work force, more than 3 times the 1970 level of 1.6 percent. Women comprised 16 percent of undergraduate engineers and earned 13.2 percent of all B.S. engineering degrees in 1983. They make up about 30 percent of computer scientists. Women engineers are more likely than men are to enter research and teaching. As are women, blacks and Hispanics are underrepresented in the engineering work force, while Asians are highly represented. In 1981, blacks and Hispanics combined made up 4.6 percent of employed engineers, and Asians comprised 2.8 percent of employed engineers.

Education and Utilization of Engineers According to an informal survey conducted by the panel, employers of engineers generally feel that young engineers are of high quality. Engineering educators, however, are concerned about the quality of engineering education, particularly in light of high student-to-faculty ratios, obsolete equipment, expanded curriculums, and the decrease in numbers of U.S.-born Ph.D. graduates. The increasingly large number of engineers graduated by foreign competitors such as Japan suggests a need to pay more attention to engineering education and to renew national attention to education in science and mathematics in elementary and secondary schools. Furthermore, the need now exists for "lifelong education" of engineers to assure currency in the face of rapid technological change.

Experience to date indicates that the breadth of scientific training incorporated into engineering curriculums permits engineers to move productively among a variety of programs.

The opinions of engineers on the effectiveness of their utilization vary widely. Preliminary results of a survey by the American Association of Engineering Societies show that, depending on the group sur veyed, positive responses from engineers asked whether they are well utilized range from about 45 percent to 70 percent.

Formal measurement of the impact of computer-based engineering tools is sketchy, but, based on the panel survey of employers mentioned above, there has been an estimated 30 percent to 40 percent improvement in productivity with the new tools.

1

Introduction

The Panel on Engineering Employment Characteristics sought to identify significant patterns and trends in demography and practice in the engineering community in the United States. The panel's goal, broadly, was to provide a data base that describes the engineering work force, its main activities, its capabilities, and its principal employers. Such a data base is a prerequisite for assessing the capability of the engineering community in meeting the nation's future needs.

In its analysis of the engineering community, the panel considered three broad groups: engineers and engineering technologists, computer specialists, and technicians. Another of the panels of the Committee on the Education and Utilization of the Engineer, the Panel on Infrastructure Diagramming and Modeling, has formally defined *engineer, engineering technologist*, and *engineering technician*. This panel subscribes to those definitions, but the available statistical data bar strict adherence to them in characterizing the engineering work force.

In this report, engineers and engineering technologists include those holding at least a B.S. degree from a traditional engineering curriculum, those with a B.S. degree from a four-year curriculum in engineering technology, and people trained in nonengineering disciplines who are working as engineers or engineering technologists. Computer specialists may be engineers, but they are not specifically so characterized and are employed in a number of areas in addition to engineering. Technicians are employed in engineering or scientific work that does not require the qualifications associated with a B.S. degree; they may hold degrees from two-year curriculums.

These classifications are fluid. An individual classed as a computer specialist, as noted above, may be a fully qualified engineer; a B.S.-level engineer may be working as a technician; an individual working as an engineering technologist may have been trained initially as a technician. In a given organization, moreover, all people who are doing engineering work may be classified as engineers, regardless of educational field and degree level.

For statistics on engineering employment, the panel relied principally on standard sources, including the Bureau of the Census, U.S. Department of Commerce; the Bureau of Labor Statistics (BLS), U.S. Department of Labor; and the National Science Foundation (NSF). Although the surveys conducted by these and other organizations supply much useful information, each is designed to meet specific needs and has no apparent reference to data from other sources. This lack of coordination leads to data bases that have gaps and inconsistencies and are poorly suited to integrated analyses. Estimates of the number of engineers in this country in 1982, for example, range from 1.2 million to 1.9 million. Given the nature of the available data, the panel believes that conclusions reached from the data are best viewed in terms of trends rather than in terms of absolute numbers. The strengths and weaknesses of the data collection system as a whole are treated in detail in the report of the Panel on Infrastructure Diagramming and Modeling.

To develop current information on the characteristics of engineering employment, particularly subjective characteristics, the panel conducted an informal survey of employers of engineers. The survey was designed to obtain the views of employers on the quality of recent engineering graduates, the utilization of engineers, and the impact of new tools on engineering productivity.

THE ROLE OF ENGINEERING

To establish a context for this report, this section briefly reviews the types of work that engineers do and the role of engineering in society at large. Engineers basically use scientific and empirical knowledge to create useful products, processes, and services. They may pursue this task in any of a number of disciplines, such as electrical, mechanical, civil, or chemical engineering. Within each discipline, however, engineers are found in a variety of functions, including research, develop ment, design, production or manufacturing, technical marketing, and engineering management.

The engineer's principal task is the conversion of knowledge to practical use—in other words, coupling technology to the marketplace. This task is clearly reflected in the demographics of the engineering work force. More than 75 percent of the engineers in this country are employed in business and industry.[1] More than 40 percent of employed engineers work directly in or manage research and development, the heart of the engineering process; about 16 percent of them work in production and inspection. Only about 2 percent are engaged in teaching.

The primary work activities of industrially employed engineers and scientists differ significantly. In development, engineers outnumber scientists by four to one. In research, on the other hand, scientists outnumber engineers by more than two to one. These differences underscore the distinction between science and engineering. The scientist fundamentally seeks new knowledge with no specific goal in mind; the engineer, even the research engineer, generally works with some practical goal in mind. The two endeavors are synergistic: engineers use the knowledge developed by scientists to open and advance new fields of engineering, which in turn create demands that lead scientists to open and advance new fields of science.

2

The Engineering Work Force

NUMBERS AND CHARACTERISTICS

Engineers

The engineering work force in this country has grown steadily for many years. The number of employed engineers almost doubled, to more than 1.5 million, between 1960 and 1982 (Figure 1). The number of engineers grew faster than the total employed population from 1900 through 1970, but lost ground relatively during the next decade because of unusually sharp growth (27.5 percent) in the employed population (Figure 2). Engineers comprised 1.4 percent of the employed population in 1980, down from a peak of 1.6 percent in 1970.

The growth in engineering employment in recent years has been especially strong in the manufacturing industries.[2] Overall employment in these industries grew less than 3 percent during 1977-1980, while engineering employment climbed 20 percent. Even in mature industries with declining employment, engineering employment remained relatively stable. These trends reflect both the impact of new technology on emerging businesses and the need of established industries to use advanced technology to upgrade their productivity and product quality to meet intense international competition.

The leading engineering disciplines, in absolute numbers, are electrical/electronic, mechanical, and civil engineering (Figure 3). The fastest-growing disciplines since 1960 have been electrical/electronics and industrial engineering (Figure 4). The "other" category of engineers (which includes environmental engineers, bioengineers, nuclear engineers, and so on) also has grown strongly, especially since about 1979, while the numbers of aeronautical engineers have grown more slowly.

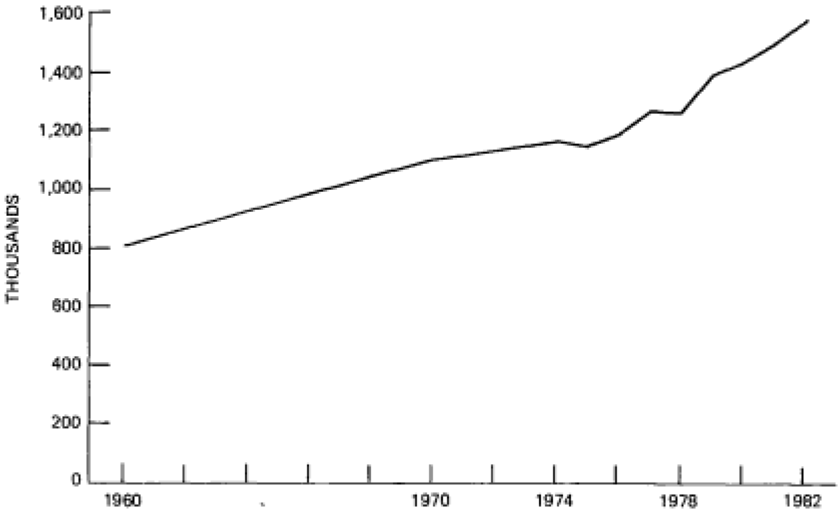

Figure 1
Employed engineering manpower, 1960-1982.
Sources: 1960: BLS Occupation/Industry Matrix 1960; 1970: BLS Occupation/Industry Matrix 1978; 1974-1982: BLS Employment and Earnings.

The growth in the numbers of electrical/electronics engineers reflects the emergence of electronics as a critical element of products, processes, and services throughout the economy. The growth in industrial engineering* in part reflects industry's efforts to improve productivity, product quality, and cost competitiveness.[2] The growth in the "other" category is due to the emergence of new fields of engineering, such as environmental engineering and bioengineering, while the slower growth in aeronautical engineering results from the relative decline of investment in the aerospace program and in new aircraft systems.

* Industrial engineering involves operations research, time-motion analysis, design of data processing and management systems, and other tasks that fall under the general heading of scientific management of industrial operations. New industrial engineering graduates numbered about 3,500 per year in the late 1970s and could meet no more than 20 percent of the demand.2 Thus, many people classified as industrial engineers have technical degrees in other fields or are upgraded technicians.

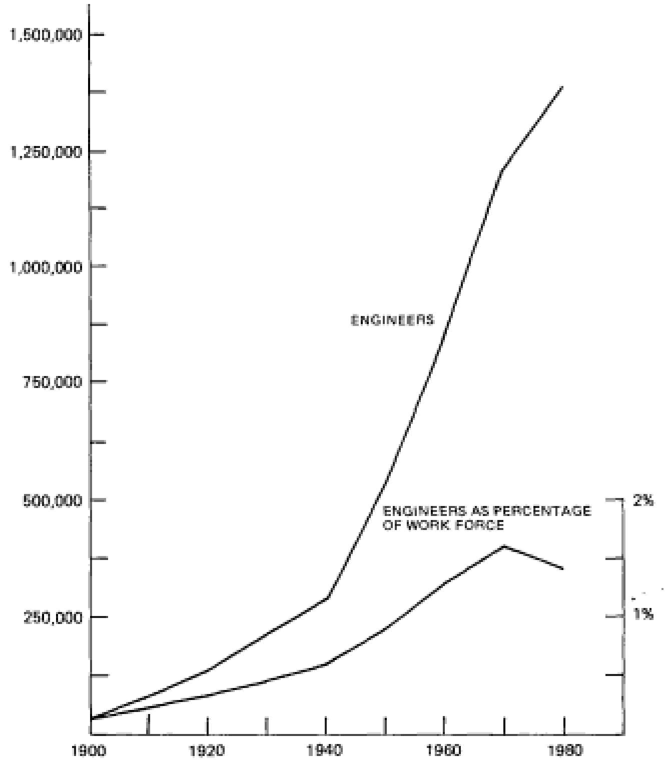

Figure 2
Total engineers and engineers as a percentage of the total civilian work force, 1900-1980.
Source: Bureau of the Census.

Computer Specialists

The past decade or so has seen the emergence of computer specialists as a major category of technical manpower. The category is separate from engineering, but many computer specialists may be converted engineers. In any event, the number of people who reported to surveys as computer specialists more than doubled during 1970-1982, to about 750,000 (Figure 5); the growth pattern was about the same for systems analysts and programmers.

We know that computer specialists make up a large and growing segment of the technically trained work force, but the specific relationship of this group to the engineering work force is unknown. (The data on the labor force reported here include all people who declared themselves computer specialists, and they work in many fields in addition to

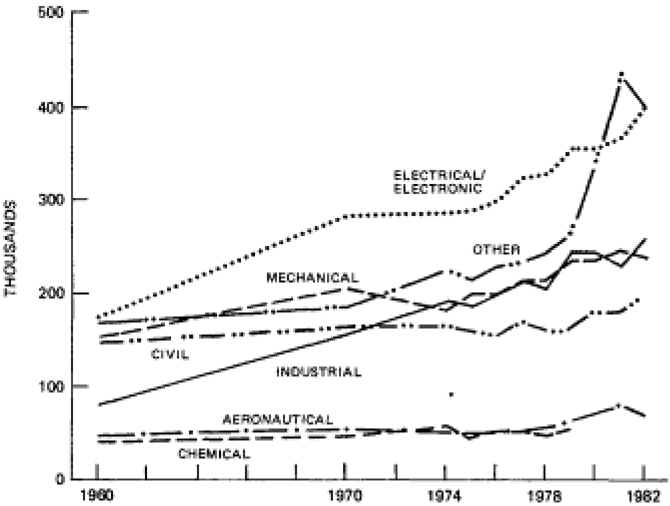

Figure 3
Employed engineers, by discipline, 1960-1982. SOURCES: 1960: BLS Occupation/Industry Matrix 1960; 1970: BLS Occupation/Industry Matrix 1978; 1974-1982: BLS Employment and Earnings.

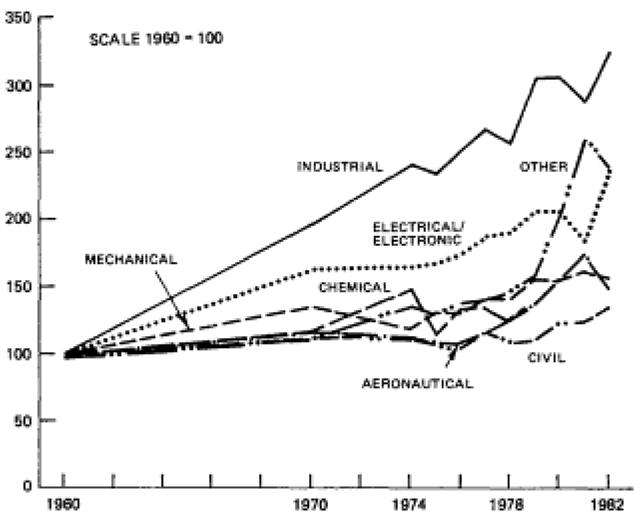

Figure 4
Employed engineers, by discipline, relative to 1960 employment, 1960-1989. Sources: 1960: BLS Occupation/Industry Matrix 1960; 1970: BLS Occupation/ Industry Matrix 1978; 1974-1982: BLS Employment and Earnings.

engineering. It is not possible to separate the computer specialists who work specifically in engineering.) Even within the engineering work force the computer specialist category is not well characterized. In some companies, for example, programming specialists working with engineers are called software engineers, not computer specialists, and become "other" engineers in the data bases. Computer hardware specialists are largely engineers (usually electrical); software specialists (systems analysts) may be engineers or mathematicians. Programmers are least likely to be engineers.

Engineering Technicians

The number of people reported to be engineering technicians in this country also has grown steadily (Figure 6) and totaled about 1.1 million in 1982. The growth rate was similar to that for engineers until 1977, but faster thereafter. During 1977-1980, employment of engineering technicians in manufacturing industries rose more than 17 percent, paralleling the growth of engineering employment in those industries.[2]

AGING AND RETIREMENT

Attrition of the engineering work force as a result of aging and retirement does not appear to be a serious problem. The data on age distribution presage no age-related overall shortage of engineers (Figure 7). This is so notwithstanding the imminence of retirement age for the many engineers who were graduated during the five years following the end of World War II. The data do suggest that the nation faces potential shortages of mechanical and "other" engineers because of an aging work force (Figures A-1 through A-7).* Age profiles for chemical and electrical engineers and computer specialists reflect relatively young work forces in these disciplines.

The engineering work force seems little affected by the change in the mandatory retirement age, from 65 to 70, that took effect in 1979. (The change was made in 1978 by amendment to the federal Age Discrimination in Employment Act.) Relatively few engineers seem to be postponing retirement. 1 The numbers of people in engineering who do work after age 65, in the panel's experience, are being offset by the early retirement of others; the average retirement age is still hovering at 62 to 63. Similarly, the average age of companies' engineering employees is holding at 42 to 44.

* All figures and tables with an A designation appear in Appendix A.

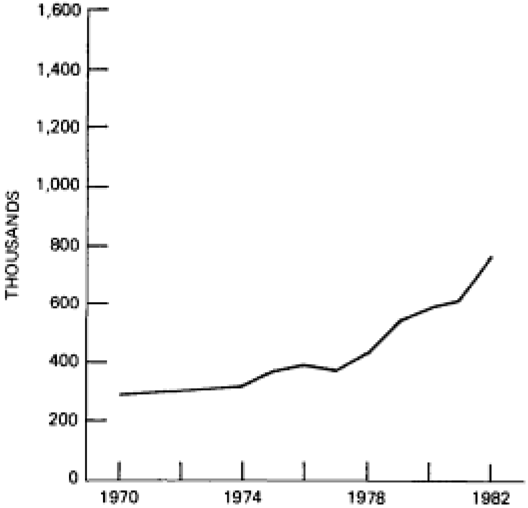

Figure 5
Employed computer specialists, 1970-1982.
Sources: 1970: BLS Occupation/Industry Matrix 1978; 1974-1982: BLS Employment and Earnings.

Figure 6
Employed engineering technicians, 1960-1982.
Sources: 1960: BLS Occupation/Industry Matrix 1960; 1970: BLS Occupation/Industry Matrix 1978; 1974-1982: BLS Employment and Earnings.

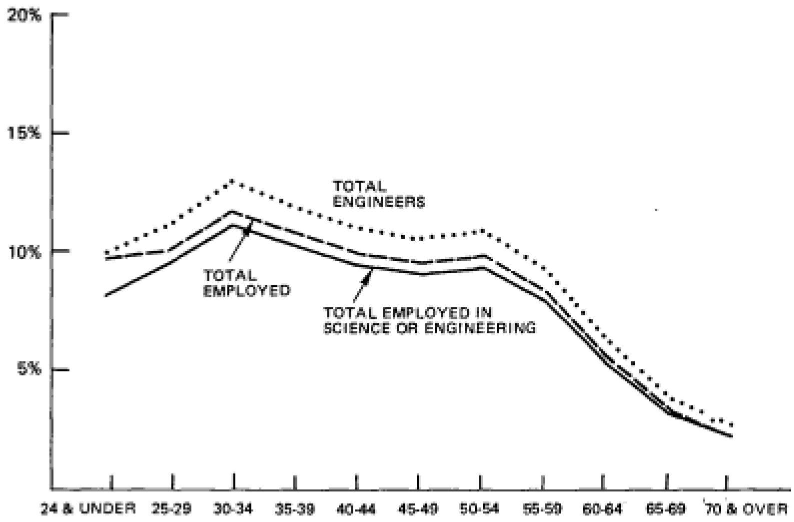

Figure 7
Age distribution of all engineers.
Sources: National Science Foundation, Bureau of the Census.

WOMEN IN ENGINEERING

Women are underrepresented in engineering, and their percentage in the field is markedly lower than in other scientific fields and professional occupations (Table 1). During the past dozen years, however, the percentage of women in the engineering profession (not necessarily holding an engineering degree) has more than tripled, from 1.6 percent of all engineers in 1970 to 5.8 percent in 1983. Similarly, the proportion of women earning the bachelor's degree in engineering rose from 0.83 percent in 1970 to 13.2 percent in 1983,[3] and women in the fall of 1983 comprised 16 percent of undergraduate engineers.[4]

The Engineering Manpower Commission has reported that the rate of entrance of women into engineering may be leveling off. Demand for women engineers is high, however, and their starting salaries are high and seem fully comparable to those being offered men, according to the College Placement Council. Thus, the reported flattening of women's enrollment may be only temporary. The ultimate percentage of women in the engineering work force is difficult to forecast, but women entering the field could well counteract a decline in enrollment that might occur because of the falling numbers of college-age males.

More than 75 percent of women engineers were employed in business and industry in 1980, according to National Science Foundation data.[5] The largest proportion of them, 12 percent, were in civil engineering; 11.7 percent were in electrical/electronics engineering; 11.7 percent in mechanical engineering; and 11 percent in chemical engineering.

TABLE 1 Percentage of Women by Scientific and Engineering Occupations

Occupation	1970	1982	1983[a]
Computer specialists	19.3	28.5	30.8
Engineers	1.6	5.7	5.8
Life and physical scientists	13.1	20.6	20.5
Operations and systems researchers	—	31.7	31.3
Social scientists	18.2	38.0	46.8
All professional and technical	40.0	45.1	48.1

[a] Data for 1983 are not precisely comparable with data for earlier years because of revision of procedures by the Bureau of Labor Statistics.
SOURCES: Bureau of Labor Statistics, Bureau of the Census.

NSF data on women engineers disagree substantially with the data reported by the Bureau of Labor Statistics. The reason may be that women with backgrounds in mathematics and science may be classified as engineers in the BLS surveys. (Further discussion of women in engineering appears in Appendix B.)

MINORITIES IN ENGINEERING

Blacks, Asians, and other minorities made up 4.6 percent of employed engineers in 1981.[1] The number of black engineers almost doubled during 1976-1981, but was still only 1.4 percent of employed engineers. The number of Asians rose some 45 percent and comprised 2.8 percent of employed engineers. Hispanics in 1981 made up about 0.4 percent of employed engineers. Thus, blacks and Hispanics are underrepresented in the engineering work force in terms of percentages of the population and percentages of all professional and related workers.[1] The foregoing data are from the National Science Foundation; more recent data, from the Bureau of Labor Statistics, show that blacks and people of Hispanic origin combined made up 4.9 percent of employed engineers in 1983.

It was clear some years ago that blacks and Hispanics were not entering the engineering and technical professions. Thus, in the early 1970s, private business, academe, and minority organizations launched seri ous efforts to bring minorities into engineering.[6] In this forward-looking effort, they made a commitment to increase the supply of minority engineers and backed it with sustained planning and financial support for programs designed to matriculate and graduate larger numbers of minority engineers annually. The National Action Council for Minorities in Engineering (NACME) was established and funded by industry to carry out the mandate.

The resulting activities included the establishment of scholarships and other types of financial aid; special academic programs, including remedial work at both the secondary and college levels; telling the engineering story to young people unfamiliar with the profession; early recruiting; and social support systems for minorities on university campuses. These efforts produced gains in enrollment and graduation of minorities in engineering. In 1983, for example, 3,800 blacks, Hispanics, and American Indians were graduated as B.S. engineers, compared with 1,300 in 1973. Freshman minority enrollment in engineering tripled in the same period. While these efforts have had an obvious-effect, recruitment of underrepresented minorities has leveled off. The number of blacks, Hispanics, and American Indians in freshman engineering classes in the fall of 1982 all declined from the previous year.[7]

Certainly, in assessing strategies for recruiting and graduating an increasing number of minority engineers, the nation must take into account certain social and cultural conditions that have impinged on the willingness of minorities to enter the engineering profession. A panel member undertook an informal investigation of minorities in engineering; the report is presented in Appendix C.

3

Utilization of Engineers

The utilization of engineers has several dimensions. Those discussed in the following section include sector and field of employment, rates of unemployment, primary activities, and mobility among primary activities. Concentration ratios of engineers in the work force are discussed in the next major section, and, finally, efficiency—the degree to which the engineer's technical abilities are being used—is addressed.

EMPLOYMENT CHARACTERISTICS

Sector and Field of Employment

According to National Science Foundation data,[8] of all employed scientists and engineers in 1982, some 75 percent were employed in business and industry. About 5 percent worked for educational institutions, 7 percent for the federal government, and 10 percent for all other employers.

On the whole, engineers tend to remain in technical work, although wide variations are found within engineering disciplines. NSF data on engineers in the labor force in 1982 show that 88 percent of them reported that they were employed in the sciences and engineering. By discipline, the percentages of those so employed ranged from 64 percent for mining engineers to 95 percent for civil and nuclear engineers.[8]

A more accurate, if narrower, evaluation can be made by tracking new graduates. Of the B.S. engineers graduated in 1978, more than 90 percent were employed in the sciences or engineering in 1980 (Table 2). Only computer specialties showed a higher percentage. About 88 percent of these B.S. engineers were employed in their degree fields. Almost 90 percent of the M.S. engineers graduated in 1978 were employed in their degree fields in 1980, and 96 percent of them were employed in the sciences or engineering (Table 3).

Rates of Unemployment

Unemployment rates for scientists and engineers traditionally have been markedly lower than for the labor force as a whole. The rate for engineers in 1982 was 1.9 percent, as contrasted with 9.7 percent for the labor force as a whole, 2.5 percent for physical scientists, and 4.9 percent for social scientists (Table 4). According to NSF data, unemployment for engineers exceeded 2 percent in only 3 of the 20 years from 1963 to 1982. It should be noted that unemployment rates for engineers and other professionals may be understated somewhat, because professionals tend to be reluctant to report that they are out of work.

Primary Activities

The predominant primary activities among all employed engineers in 1982 were development, management, and production/inspection

TABLE 2 1980 Utilization Rate of Scientific and Engineering Training: 1978 Bachelor' s Degrees

Degree Field	Number of Bachelors	Employed in Field of Degree (%)	Employed in Other Science and Engineering Field (%)	Employed in Field Outside of Science and Engineering (%)
Computer specialties	6,800	88.1	4.9	7.0
Engineering	51,600	87.8	4.1	8.1
Life sciences	46,400	38.9	14.0	47.1
Mathematics	10,100	10.9	51.4	37.7
Physical sciences	8,400	40.5	33.3	26.2
Chemistry	5,600	47.9	30.7	21.4
Physics	1,800	20.4	59.2	20.4
Social sciences (including psychology)	85,400	10.6	8.5	80.9

SOURCE: National Science Foundation.

TABLE 3 1980 Utilization Rates of Scientific and Engineering Degrees: 1978 Master's Degrees

Degree Field	Number of Bachelors	Employed in Field of Degree (%)	Employed in Other Science and Engineering Field (%)	Employed in Field Outside of Science and Engineering (%)
Computer specialties	2,700	84.7	11.1	4.2
Engineering	15,200	87.0	9.2	3.8
Life sciences	7,600	69.5	6.7	23.8
Mathematics	2,600	41.8	33.5	24.7
Physical sciences	2,300	56.5	34.8	8.7
Chemistry	1,300	76.7	16.3	7.0
Physics	800	35.7	60.7	3.6
Social sciences (including psychology)	10,900	54.1	10.1	35.8

SOURCE: National Science Foundation.

TABLE 4 Unemployment Rate Among Scientific and Engineering Manpower, 1974-1982

Field	1974	1976	1978	1980	1982[a]
Computer specialists	0.5%	1.3%	0.5%	0.6%	1.1%
Engineers	1.3	1.9	0.8	1.0	1.9
Aeronautical	NA	2.8	1.2	1.1	1.8
Chemical	NA	1.0	1.1	1.1	3.0
Civil	NA	2.0	1.1	1.2	2.0
Electrical	NA	1.5	0.7	0.8	1.2
Mechanical	NA	1.9	0.5	0.7	2.1
Other	NA	2.1	0.9	1.0	2.0
Life scientists	2.0	1.4	1.2	1.1	2.4
Mathematicians	2.1	2.7	0.8	0.9	2.1
Physical scientists	NA	2.4	1.7	1.8	2.5
Social scientists	2.4	1.7	1.5	1.6	4.9
Professional, technical, and kindred[b]	NA	3.2	2.6	2.5	3.0
Total labor force	NA	7.7	6.1	7.1	9.7

NOTE: NA = not available.
[a] Data for 1982 are not precisely comparable with data for earlier years.
[b] Category revised by BLS and now called "professional workers."
SOURCES: National Science Foundation, Bureau of Labor Statistics.

TABLE 5 Primary Activities of Employed Engineers, 1982 (percent)

Activity	All Engineers	Women Engineers
Research		
Basic	0.9	4.1
Applied	3.8	6.8
Development	27.9	15.2
R&D management	8.7	3.4
Other management	19.3	16.6
Teaching	2.1	7.3
Production/inspection	16.6	13.6
Other[a]	20.7	33.0

[a] Consulting, reporting, statistical work, computing, other, no report.
SOURCE: Unpublished National Science Foundation tabulations, based on 1982 Post-Census Survey of Scientists and Engineers—July 1984.

(Table 5). NSF data for 1976-1980 indicate that, compared with other scientists, engineers were less likely to be involved in research, analysis, and teaching; more likely to be involved in development and production; and slightly more likely to be involved in management (see Figures A-8 and A-9). During the same period, engineers themselves became increasingly involved in production and analysis and somewhat less involved in management. The proportion of engineers involved in teaching showed little change during 1976-1980, but was relatively low, about 2.3 percent, compared with 15.7 percent for all scientists (only about half of the engineers employed by educational institutions are actually engaged in teaching).

The pattern of primary activities differs somewhat among male and female engineers (Table 5). The percentage of women engineers engaged in research in 1982 was 10.9 percent, or more than twice the percentage of all engineers. Women were less represented in managerial jobs, reflecting both their more recent entry into engineering and, to some unknown extent, their lower level of acceptance by the profession. A lower percentage of women than of all engineers was in production/inspection and other tasks, but a large percentage of women, as with all engineers, was employed in development.

Doctoral engineers also differ from" all engineers" in primary activities (Table 6). As one would suspect, the highest percentage of doctoral engineers (23.7 percent in 1981) was involved in research, with teach

TABLE 6 Primary Activities of Doctoral Engineers, 1973 and 1981

	1973		1981	
Activity	Number	%	Number	%
Research	8,300	23.2	13,500	23.7
Development	5,000	14.0	9,900	17.4
R&D management	8,300	23.2	10,300	18.1
Other management	2,200	6.1	4,900	8.6
Teaching	8,800	24.6	10,600	18.6
Other[a]	3,600	8.9	7,500	13.6
Total	35,800		57,000	

[a] Consulting; production/inspection; sales and professional services; reporting, statistical work, and computing; other; no report.
SOURCE: *Science Indicators, 1982* (Washington, D.C.: National Science Board, 1983).

ing the second largest activity for Ph.D.s. As the table shows, in the period 1973-1981, the percentage of doctoral engineers in development increased from 14.0 percent to 17.4 percent, and the percentage in teaching declined from 24.6 percent to 18.6 percent, although the absolute numbers in teaching increased. The percentage doing research remained essentially constant.

Mobility Among Primary Activities

Engineers move regularly among primary work activities; they also move entirely out of engineering and sometimes return. NSF data on the mobility of a specific cohort of experienced engineers show a net flow into management during 1972-1978, a net flow out of production and R&D, and a small net flow out of teaching (Tables A-1 through A-4). Later data show a small net flow out of teaching during 1980-1981 and a small net flow into teaching during 1981-1982.[9] The data also show a net flow of 24 percent out of engineering during the period 1972-1978 (Table 7). This outflow was slightly higher than for life and physical scientists and computer specialists but much lower than for mathematicians.

Companies encourage internal movement of engineers to broaden their experience. The most common move is from one assignment to another at the same location. Engineers may also be moved geographically—to provide experience at different facilities, for example—but for a variety of reasons such moves are being less readily made. One of the reasons is the expense of moving; another is the growing number of two-career couples.

TABLE 7 Occupational Mobility of Experienced Scientists and Engineers: 1972-1978 (thousands)

Occupation	1972 Total	Inflow	Outflow	Net Flow 1972-1978
Computer specialists	66.5	8.6 (12.9%)	23.4 (35.2%)	-14.8 (22.3%)
Engineers	393.5	12.8 (3.2%)	107 (27.2%)	-94.2 (24%)
Life scientists	67.8	4.3 (6.3%)	19.2 (28.3%)	-14.9 (22%)
Mathematicians	27.6	2.3 (8.3%)	11.5 (41.7%)	-9.2 (33.3%)
Physical scientists	80.3	7.6 (9.5%)	23.4 (29.1%)	-15.8 (19.6%)

SOURCE: National Science Foundation.

The Dual Ladder Although engineers can benefit from periodic reassignment, some prefer to stay in purely technical work as opposed to, say, administration, marketing, or plant operations. Such people comprise a valuable technical asset. Traditionally, however, the choice of purely technical work meant a sacrifice in salary and status, because progress in one's company normally entailed assignments to other kinds of work. To ease this problem, larger companies have set up dual-ladder arrangements, which are designed to permit engineers to move up a technical ladder, in terms of salary and status, in parallel with their counterparts on the management ladder. Emerging after World War II, the dual-ladder approach has since proved very useful to both individual engineers and management. The panel members, however, believe that people with broader capabilities and interests will continue to receive greater economic rewards.

CONCENTRATION RATIOS

A broad measure of the utilization of engineers is their percentage in the total work force of an economic sector or industry. This percentage—the concentration ratio—is a crude indicator of the technological intensity of the sector or industry. Concentration ratios for technicians and computer specialists also are indicators of technological intensity. This section outlines concentration ratios for engineers, technicians, and computer specialists in major economic sectors and industries.

Engineers

Of the major economic sectors, the federal government, excluding the Postal Service, has the highest concentration ratio for engineers. The ratio rose from about 3.25 percent in 1960 to about 5 percent in

TABLE 8 Concentration Ratios (percent of total employment) of Engineers, Technicians, and Computer Specialists in Major Sectors and Industries, 1960, 1970, and 1980

	Year	All Industry	Manufacturing Industry Total	Durable Goods	Nondurable Goods	Public Administration
Engineers	1960	1.33%	2.69%	4.05%	0.97%	2.66%
	1970	1.58	3.28	4.65	1.29	3.00
	1980	1.42	3.29	4.56	1.35	1.92
Technicians[a]	1960	0.96	2.11	2.75	1.29	1.73
	1970	1.05	2.08	2.55	1.39	1.91
	1980	1.13	2.32	2.74	1.74	1.60
Computer specialists	1960	—	—	—	—	—
	1970	0.44	0.70	0.93	0.37	1.18
	1980	0.61	0.84	1.13	0.41	1.34

[a] Includes both engineering and science technicians.
SOURCE: Bureau of the Census.

1978, according to the Bureau of Labor Statistics. Other data, from the Bureau of the Census, indicate that the ratio for engineers in public administration—all government, including state and local—rose from 2.7 percent in 1960 to 3.0 percent in 1970, but then declined to 1.9 percent in 1980 (Table 8).

Engineers employed in all industry far outnumber employees in other technical disciplines. The concentration ratio grew rapidly through 1970, but then, as shown in Table 8, declined slightly through 1980 to about 1.42 percent. The decline was due in part to the advent of computer specialists as a separate occupational category. In manufacturing industries, the concentration ratio is more than twice as high as it is in all industries.

Concentration ratios for engineers vary widely across industries (Table 9). The ratios for the primary metals, fabricated metals, and motor vehicle industries were considerably below the mean (4.56 percent) for durable goods industries in 1980. In electronic computing, aircraft, and commercial R&D, increases in the ratios for computer specialists may have occurred at the expense of the ratios for engineers. As noted earlier, many computer specialists may be converted engineers.

Examination of concentration ratios indicates that one engineering discipline traditionally has tended to be dominant in each industry: mechanical engineers in the machinery industry, electrical engineers

TABLE 9 Concentration Ratios of Engineers, 1960 and 1980

Industry	1960	1980	Trend
Primary metals	2.19%	2.16%	Down
Fabricated metals	4.10	2.33	Down
Chemicals	3.79	4.03	Up
Communications	4.00	3.88	Down
Machinery (except electrical)	4.20	4.80	Up
Electrical machinery	6.97	7.10	Up
Electronic computers	10.71 (1970)	9.55	Down
Motor vehicles	2.49	3.75	Up
Aircraft	12.64	15.68	Up
Engineering services	27.07	25.24	Down
Commercial R&D	15.01 (1970)	12.74	Down
Computer programming	3.77 (1970)	2.48	Down[a]

[a] The result of rapidly growing numbers of computer specialists.
SOURCE: Bureau of the Census.

in electrical machinery, chemical engineers in the chemical industry, and so on (see Figures A-10 through A-14). This pattern suggests that the balance among engineering disciplines in an industry should change as its products change. When the automobile industry, for example, began to reduce the weight of cars to improve fuel efficiency, automobile manufacturers began to hire more civil engineers to do the necessary structural analyses. Similarly, the percentages of electrical and computer engineers in the aerospace industry have been growing steadily as the electronics and computer content of major aerospace systems has grown.

Technicians and Computer Specialists

Concentration ratios for engineers, technicians, and computer specialists in all industries are compared in Table 8. Among major economic sectors, the ratio for technicians exceeds that for engineers only in nondurable goods. Among industrial sectors, the technician ratio is higher only in chemicals, computer programming, and commercial R&D (see Table A-5). The concentration ratios for computer specialists are lower than those for engineers and technicians in all sectors but electronic computers, computer programming, and business management, where they exceed both. The ratios for computer specialists are growing steadily, however.

These concentration ratios are restated in terms of numbers of technicians and computer specialists per engineer in all industries in Figure 8.

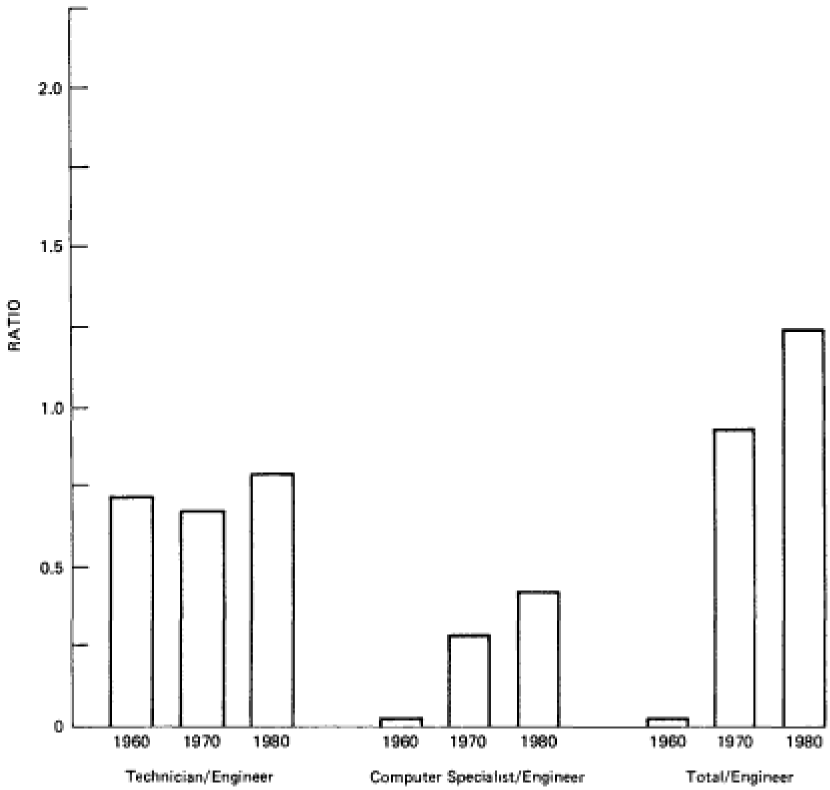

Figure 8
Technicians and computer specialists per engineer, all industry.
Source: Bureau of the Census.

The rationale is that both provide support for engineers. Technicians are commonly viewed as working in support of engineers (or scientists), but the technician classification in industry, as reported in various surveys, covers many tasks not in support of engineers. It is not possible to separate engineering support tasks from the survey data. Even so, the ratio of technicians to a given engineering work force provides at least a crude measure of the degree to which they are freeing engineers for tasks that require engineering qualifications. Computer specialists may or may not support engineers directly or indirectly.

EFFICIENCY OF UTILIZATION

Assessments of the efficiency of utilization of engineers—the extent to which their technical abilities are being used—are necessarily sub jective. Considerable research was done on the subject in the late 1960s and early 1970s, but recent information is scarce.

To broaden its basis for judgment in this and related areas, the panel conducted an informal survey of employers of engineers. The survey solicited management's view of the efficiency of utilization of engineers, the impact of new technology on engineering productivity, and the difficulty of finding quality engineering graduates. The form employed in the survey and a summary of the results appear in Appendix D. The form was mailed to some 350 firms, and 107 responses were received. The survey did not employ a scientific sampling procedure; smaller consulting firms, for example, are overrepresented. For this reason, and because of the relatively small number of responses, the results should be viewed with caution.

The results of the panel's survey show in part that, in senior management's opinion, computer hardware engineers, computer software engineers, and civil engineers are the most fully utilized (70 percent and higher), while aeronautical, chemical, electronics, and industrial engineers are somewhat underutilized (46 percent and lower). Neither electronics nor electrical engineers were reported as being utilized as fully as the panel had expected. It is not clear, however, what levels of utilization ought to be considered acceptable. Also, in the panel's experience, management tends to estimate utilization higher than do individual engineers.

Substantial difference of opinion among engineers is found in the preliminary results of a study of utilization being conducted by the American Association of Engineering Societies.[10] The reported results, when engineers were asked if their utilization was excellent, showed a positive response range of 47 percent to 71 percent, depending on the group surveyed.

Views of individual engineers that may be related to efficiency of utilization were obtained in other surveys; the results are shown in Tables 10, 11, and 12. In particular, the quite low levels of satisfaction shown in Table 11 suggest correspondingly low levels of utilization.

Impact of New Technology

The efficiency of utilization of engineers is being affected by new technologies, such as computer-aided design (CAD) and drafting. These and related technologies are still relatively new, however. Although they are definitely increasing the productivity and quality of engineering, their net effect on engineering and on industry as a whole cannot be forecast with confidence.

Computer-aided design unquestionably provides the capability to

TABLE 10 Survey Results: Engineers' Views of Their Work, According to National Engineering Career Development Study

Respondents:	Percent
Satisfied with choice of occupation	72[a]
Satisfied with career progress	61
Satisfied with work in present job	80

NOTE: Total sample = 2,852 experienced engineers.

[a] 72% of responses fell into the two most positive categories of a 5-point scale.

SOURCE: W. K. LeBold, K. W. Linden, C. M. Jagacinski, and K. D. Shell "National Engineering Career Development Study: Engineers' Profiles of the Eighties." Purdue University, West Lafayette, Ind., June 1983.

TABLE 11 Survey Results: Engineers' Views of Their Work (Civilian Engineers in Joint Logistics Commands)

Respondents:	Percent
Satisfied with work assignments	37[a]
Job uses individual's potential	28
Working as engineer in federal government is satisfying	23

NOTE: Total sample = 1,609 experienced engineers.

[a] Includes always/often responses.

SOURCE: "Civilian Engineer Recruitment, Retention, and Use Throughout the Joint Logistics Commands," prepared by Joint Panel on Civilian Personnel Management established by Joint Logistics Commanders, U.S. Department of Defense, Washington, D.C., Oct. 30, 1981.

TABLE 12 Survey Results: Engineers' Views of Their Work (Engineering Graduates, University of Illinois)

Respondents:	10 Years After Graduation (%)	5 Years After Graduation (%)
Consider engineering degree relevant to work	69.1[a]	85.1[a]
Personally satisfied with engineering work	82.9[b]	87.2[b]

NOTE: Surveys started in 1977 and were conducted each year for those graduating 10 years and 5 years earlier.

[a] Responses of "most or all" and "some" on a 4-point scale. Scores averaged across six surveys (1977-1982).

[b] "Yes" response on yes or no question. Scores averaged across six surveys (1977-1982).

SOURCE: College of Engineering, University of Illinois.

increase the engineer's productivity in terms of hourly output. The value of the increase cannot readily be assessed, however, because CAD also changes the nature of the work. It may permit the engineer to design a part with greater precision, for example, or to consider more options, or, more importantly in many cases, to shorten development lead time. But comparable tasks have seldom been carried out simultaneously with and without a computer-based system, so costs cannot be compared directly. Further, a company engages in a good deal of analysis before deciding to invest in a computer-aided system, but once the system is installed, the emphasis is on making it work. Thus, after-the-fact analysis is not done routinely.

The panel's informal survey of employers of engineers covered four elements of new engineering technology: computer-aided drafting, computer-aided design, computer-aided manufacturing, and engineering information systems. Fewer than half of the respondents that had such systems had formally evaluated them quantitatively, but, on average, productivity improvement was estimated in the range of 30 percent to 40 percent.

Because certain design programs can be incorporated into CAD systems and because of interactive graphics, designing with CAD in some jobs may require less technical direction than designing without CAD. Most importantly, these new computer-aided tools permit increasingly sophisticated products to be designed in less time with substantially greater accuracy and with greater cost-effectiveness.

4

Quality of the Work Force

A critical characteristic of a work force is its quality. Some observers have expressed concern that the quality of the engineering (and scientific) work force in this country may be declining. This concern is not consistent with the results of the panel's informal survey of employers of engineers (see Appendix D) and may reflect not so much a decline in quality as rising expectations of what engineers should be able to do or guarantee. On the other hand, evidence that might support the negative view includes the difficulties in the construction and operation of nuclear power plants, the many recalls of automobiles to correct engineering defects, and the problems that generally afflict U.S. industries, especially the traditional industries.

Industrial decline can have many interrelated causes in addition to inadequate engineering. They include shortsighted management; national priorities that have assigned a large percentage of highly skilled engineers to defense and space programs rather than to industrial production; investment in foreign countries having relatively cheap labor; and many others.

CURRENT VIEWS OF QUALITY

There is no direct measure of the quality of the engineering work force. Opinions on the question differ, and these differences are typified by the results of the panel's informal survey and the contrasting academic analysis, as discussed in this section.

More than half of the industrial respondents to the panel's survey of employers reported difficulty in finding quality graduates in computer hardware, computer software, electrical, and electronics engineering. Difficulty in finding quality graduates in other engineering disciplines ranged from 14 percent of respondents for civil engineers to 47 percent for mechanical engineers. Nevertheless, relatively few respondents noted a decline in the quality of recent graduates, and the predominant opinion was that quality is rising, although most forefront industrial organizations believe in and provide for some training above the B.S. level.

The academic appraisal is less sanguine. The initial premise is that the scope of engineering and the knowledge required in the practice of engineering have broadened steadily over the years and will continue to do so very rapidly. The conceptual level of that knowledge and, consequently, the complexity of engineering practice also are rising significantly, but at a more moderate rate. Historically, the engineering community has kept pace with the scope and amount of available knowledge through professional literature, computers and technical course work, and by means of its own growth in numbers. An important change has occurred, however.

For many years, while the average level of secondary education throughout the United States population was rising, the average level of undergraduate education in engineering rose correspondingly. But 15 or 20 years ago, the average level of secondary education peaked and began to decline. The average level of engineering education has declined as well. In terms of numbers awarded annually, bachelor's degrees in engineering rose about 75 percent between 1968 and 1982, while numbers of master's degrees stayed about the same; numbers of doctoral degrees, which peaked in 1972, had declined by 1982 to about the level of 1968. Moreover, doctoral degrees awarded to U.S. citizens in 1982. were down more than 40 percent from the peak of 1972 and more than 20 percent from 1968.[11]

Thus, during a time of rapid growth in the scope and conceptual level of knowledge required to practice engineering successfully, the average degree level of education of our younger engineers has actually declined. That this trend might have a long-lasting, harmful effect on engineering education is a source of concern. A similar harmful effect on industrial innovation and competitiveness might also occur and jeopardize this country's posture in world markets. Continuing education in industry has grown during the past 15 years but can only partly counteract the general downturn.

Academics believe that they can explain the apparent conflict between this analysis and other opinions which hold that the quality of recent engineering graduates is at least as high as it has ever been. They argue that engineering schools in recent years have been able to restrict their undergraduate enrollments to only the best students. High school seniors planning to major in engineering have scored well above the average for college-bound seniors on both the verbal and mathematical parts of the Scholastic Aptitude Test.[1] Quantitative scores on the Graduate Record Examination have remained high among engineers headed for graduate school. These factors, educators contend, have tended to obscure the negative effects of problems such as high student-to-faculty ratios and obsolete equipment. Thus, what employers may be seeing in young engineers, according to the academic argument, is basic intelligence and aptitude, not necessarily depth of education.

Opinions of the quality of the engineering work force are varied, as we have seen, and necessarily subjective. Nevertheless, the issue is critical and warrants continuing serious attention.

5

Resilience of the Work Force

Resilience in the engineering work force is desirable, but not readily measured. By resilience we mean basically the ability to adapt smoothly to new circumstances. One example would be effective and reasonably rapid exploitation of new technologies. Another is efficient accommodation to sudden changes in demand for engineering work entailed by a shift in emphasis from the development of space systems to the revitalization of manufacturing facilities on a massive scale.

A classical instance of a true change in technology was the shift from the vacuum tube to the transistor and related solid-state devices over a period of some 20 years. Typical crash programs include the Apollo manned space program and the drive to improve the nation's energy efficiency, sparked by the Arab oil embargo of the early 1970s. The engineering community appears to have reacted with relative dispatch in both cases.

On the whole, it can be argued that in no instance since World War II have deficiencies in the quantity or quality of the engineering effort constrained the development of new, high-priority technologies for technically based programs or the application of new or existing technologies; social, political, and economic factors have posed far more serious constraints. It can also be argued, however, that the application of the nation's most capable engineering resources to "priority" issues may have diverted attention from other pressing engineering tasks. Current U.S. industrial problems and reduced industrial growth suggest a need for concurrent, quantum development rather than sequen tial, incremental efforts. They suggest as well that a larger technical resource would provide a stronger economy and would improve the quality of life.

A degree of resilience is built into the practice of engineering. The broad content of physical and engineering science in present undergraduate curriculums permits mechanical engineers, for example, to handle work in electrical engineering, or electrical engineers to become aerospace engineers. This is especially true during an engineer's first decade out of college.

A key to this form of resilience is the universality of physical and mathematical principles. Advanced engineering programs involving innovative products and processes must find leaders among those who conceive or understand the development that is the impetus for the work. Nevertheless, the relevance of fundamental scientific principles can provide a basis for valuable contributions by engineers trained during a prior state of art.

Companies must have the resilience to be able to cope at times with sudden surges in demand for engineering work over finite periods. Again, the universality of scientific and mathematical principles permits the use of contract engineering firms or self-employed engineers to augment in-house staff as required. The true extent of such contract consulting support, however, is not accurately quantifiable.

TECHNOLOGICAL OBSOLESCENCE

An important element of resilience in engineering is technical currency. Both companies and individual engineers can become technologically obsolescent. Engineering schools update their programs and curriculums in response to academic and industrial R&D that produces significant changes in technology, but the process is protracted and has little immediate effect on the engineering work force. Thus, achieving technical currency within a business is the responsibility of management. Continuing education to upgrade the capabilities of personnel, including technicians, can be effective, and accelerated programs are sometimes used.

There is a tendency to equate obsolescence in individuals with age, but this view is usually oversimplified. Depending on the discipline, obsolescence can begin to overtake engineers as early as 10 years after graduation. Those who wish to stay abreast of developments in their fields can read the literature and generally have access to formal courses or other programs offered by their employers, their professional societies, or educational institutions; however, there is reason for concern that far too few participate in such programs. The critical factor is motivation. Over time, engineers' interests can shift from purely technical matters to other important aspects of the technological enterprise. Up to the present time, many experienced engineers have served industry extremely well in jobs that often did not require state-of-the-art knowledge or that required it only in a narrow area. In today's fast-paced, worldwide competition, however, it is increasingly recognized that a technological edge is a prerequisite for the development of successful products and services.

In view of their need to do continuously useful work today, technological obsolescence for engineers must be recognized as a problem. Increasingly, it is management's job to provide an atmosphere that motivates the individual engineer to remain up to date technically. Computer-based tools continue to change the practice of engineering dramatically and challenge the engineer's ability to remain current.

6

International Comparisons

The characteristics of engineering work forces abroad are pertinent to issues of international industrial competitiveness, and the greater emphasis on product and process technology abroad is a serious concern, but the panel had too little specific information in these areas to support precise conclusions. The impressive technical progress of Japan led to a study by the panel of available data on that nation's engineering capabilities, from which the following remarks are drawn. The data must be viewed as approximate at best.

Throughout the 1970s, Japan produced at least twice as many B.S. engineers per 10,000 population as the United States and on the order of 10 percent more in absolute numbers (Table 13). From 1965 to 1980, the number of scientists and engineers employed in R&D increased 30 percent in the United States, 82 percent in West Germany, 131 percent in Japan, and 140 percent in the U.S.S.R. (Table 14).

Definitional problems no doubt exist. The relatively high number of scientists and engineers reported to be working in R&D in the U.S.S.R., for example, does not square with the apparent lag in that nation's industrial technology. Even so, however, Japan is clearly producing more technically trained people than the United States is.

It has been reported that only about half of Japan's engineers actually enter the engineering profession.[12] The rest become civil servants or managers in industry. In fact, about half of Japan's senior civil servants and industrial directors are said to have engineering qualifications, a circumstance that must be contributing to that nation's industrial success.

TABLE 13 Output of Engineering B.S. Degrees for United States and Japan: 1971, 1975, and 1980

	Engineering Degrees (B.S.) (thousands)		Engineering Degrees per 10,000 Population[d]	
Year	USA[a]	Japan[b,c]	USA	Japan
1971	50.0	55.9	2.44	5.30
1975	46.9	65.4	2.19	5.86
1980	68.9	73.5	3.1	6.22

NOTE: Initial tabulations provided by National Center for Education Statistics.
[a] National Center for Education Statistics.
[b] *Statistical Abstract of Education, Science and Culture*. 1981 ed. Ministry of Education, Science and Culture, Japan.
[c] *UNESCO Statistical Yearbook*.
[d] U.S. Bureau of the Census.

TABLE 14 Scientists and Engineers Employed in R&D, 1965-1980

Country	% Increase From 1965 to 1980	Total (thousands)
United States	30	645 (1980)
West Germany	82	111 (1977)
Japan	131	273 (1978)
U.S.S.R.	140	1,254 (1980)

SOURCE: *Science Indicators, 1980* (Washington, D.C.: National Science Board, 1981).

The data suggest that the concentration ratios for engineers in Japanese industry may be higher than in this country. To assess the effects of high or low concentration ratios, however, one must compare the ratios for more and less effective companies or nations in particular industries, and the panel had too little information to do so. Even if the data were available, one would have to look at other variables, including management and national political decisions.

7

Supply and Demand for Engineers

The inability to accurately forecast developments such as levels of economic activity and capital expenditure and societal events in general suggests the difficulty inherent in designing systems for predicting or managing supply and demand for engineers in any meaningful way. The panel certainly was not qualified in this area, but it did examine several factors that bear on supply and demand as well as existing predictions.

ENGINEERING SALARIES

One indication of demand for engineers is their salaries. The most recent earnings surveys show that engineers remain among the best paid of all employed professionals. The National Survey of Professional, Administrative, Technical, and Clerical Pay, which provides detailed data over time, shows that engineers as a group earn more than chemists, accountants, and engineering technicians (Figure 9). The survey also shows that, since 1963, the differential enjoyed by engineers has remained essentially the same, despite some wide variations in year-to-year salary increases. The average salaries of none of these groups have totally kept pace with inflation (Figure 10).

The picture for entry-level engineers is somewhat different. They earn more than their counterparts in other fields, but the differential increased after 1963 and became especially noticeable in 1977 (Figure 11). By 1983, entry-level engineers were doing markedly better than

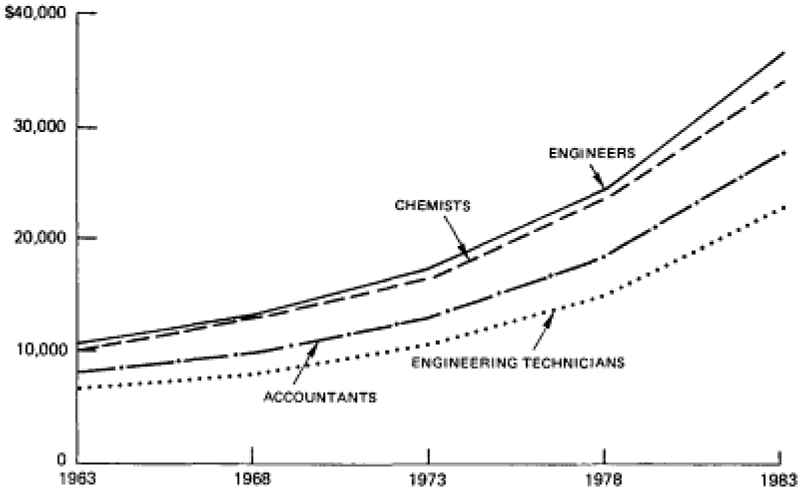

Figure 9
Median salaries for engineers, chemists, accountants, and engineering technicians in private industry, 1963-1983.
Source: National Survey of Professional, Administrative, Technical, and Clerical Pay.

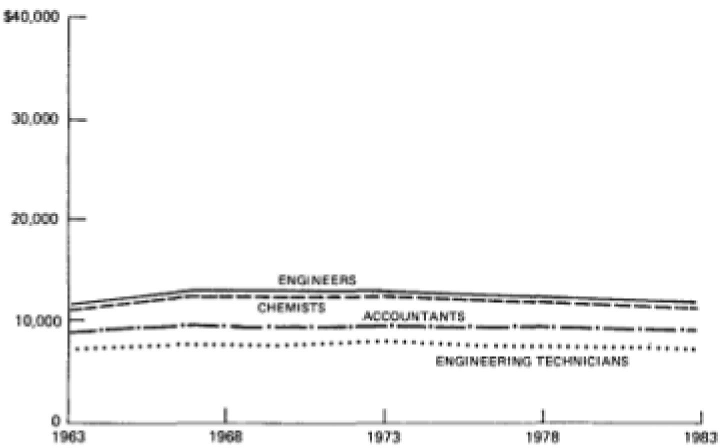

Figure 10
Median salaries for engineers, chemists, accountants, and engineering technicians in private industry, 1963-1983 (constant 1967 dollars).
Sources: Bureau of Labor Statistics; National Survey of Professional, Administrative, Technical, and Clerical Pay.

entry-level people in other fields and had slightly outpaced inflation (Figure 12). The differentials among entry-level chemists, accountants, and engineering technicians, meanwhile, remained about the same. The increase in the salary differential for entry-level engineers suggests that some employers may have considered new engineers, particularly computer-literate engineers, in short supply.

Salary data also shed light on the relative reluctance of engineering students to pursue the Ph.D. Although the data are not definitive, it appears that the cumulative total income of a Ph.D. engineer does not catch up with that of a B.S. engineer for some years—nearly 20 years by one reckoning (Figure 13)—after each receives the B.S. After that, the Ph.D. clearly does better than a B.S. engineer.

The salaries paid by industry are said to be a major attraction for academic scientists and engineers, but salary and mobility data do not appear to support this view conclusively. Industry pays doctoral mathematicians, for example, about 30 percent more than universities pay them, but universities have no trouble attracting mathematicians. Industry pays engineers about 15 percent more than universities do, yet universities have much more trouble attracting Ph.D. engineers than they do mathematicians. Industrial-academic comparisons may be deceptive because they involve median salaries. For tenure-track positions, colleges and universities typically attempt to hire the best doctoral engineers available, and these people may command significantly higher than the median salaries in industry. In any event, individual choices of academe or industry doubtless involve factors in addition to salary.

The federal government, like educational institutions, pays engineers less than they can earn in industry. Federal salaries are limited by civil service regulations. The effect is seen in a comparison of salaries at the Naval Research Laboratory (NRL) with those at three government laboratories operated by civilian contractors (government-owned, civilian-operated, or GOCO labs).[13] The director of NRL in 1983 was earning $66,000 per year. The directors of two of the GOCO labs were earning $110,000, and the director of the third was earning $90,500. Similarly, an outstanding new doctoral engineer could command $30,400 at NRL and $50,000 at the three GOCO labs. Federal laboratories are reported to be having difficulty attracting and retaining engineers because of the salary restrictions imposed by the civil service system.[13]

HIRING PRACTICES

Companies with large engineering staffs, such as General Electric, Westinghouse, and the large aerospace companies, tend to hire engi

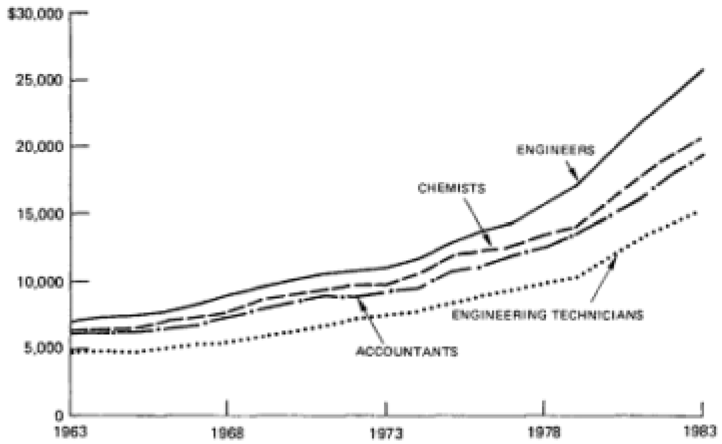

Figure 11
Entry-level median salaries for engineers, chemists, engineering technicians, and accountants in private industry, 1963-1983.
Sources: Bureau of Labor Statistics; National Survey of Professional, Administrative, Technical, and Clerical Pay.

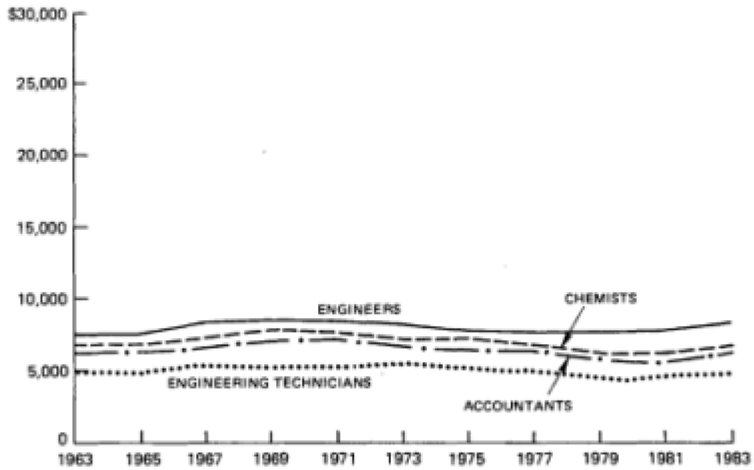

Figure 12
Entry-level median salaries for engineers, chemists, accountants, and engineering technicians in private industry, 1963-1983 (constant 1967 dollars).
Source: Bureau of Labor Statistics; National Survey of Professional, Administrative, Technical, and Clerical Pay.

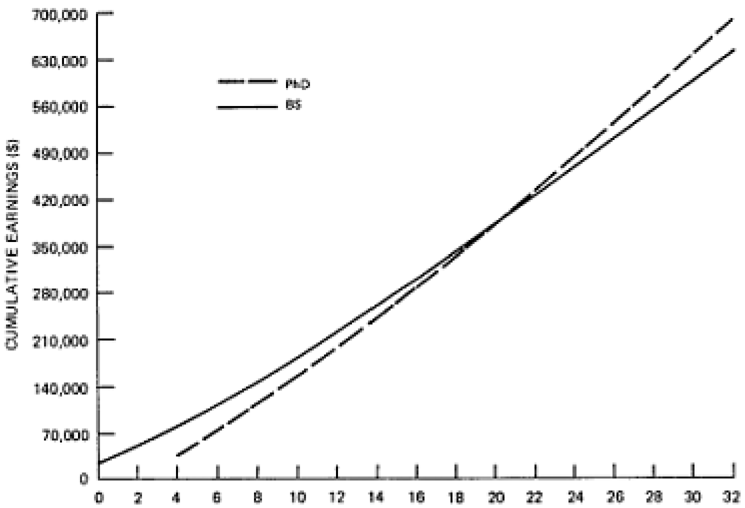

Figure 13
Cumulative earnings of B.S./Ph.D. engineers.
Sources: Panel on Infrastructure Diagramming and Modeling, Committee on the Education and Utilization of the Engineer.

neers on a continuing basis except in times of severe economic retrenchment. At the least, this hiring practice makes up for attrition, which is steady, if small, in a large company. The tendency is to hire predominantly new graduates rather than seasoned engineers. The new graduates are sprinkled across the disciplines and are considered a source of up-to-date technology as well as replacements for departing employees.

In times of long-term growth, the percentage of experienced engineers recruited increases. Short-term needs for experienced engineers with specific skills are often satisfied by retaining contract engineers from engineering service companies.

In periods of low growth, large companies adjust their technical work forces so that they can hire at least some engineers from schools whose graduates have worked out well; such hiring permits them to preserve working campus relationships and upgrade their staffs. These companies usually .have full-time recruiters who visit schools, participate in job fairs, conduct open houses, and so forth.

Newly recruited engineering graduates often are not hired for specific jobs. Instead, they enter organized programs involving successive assignments to different operating elements of the company. These programs generally range from six months to three or more years and are carefully developed to acquaint the new graduate with the company, its procedures, and the responsibilities of various departments. Upon completing the program, the employee is either given or permitted to choose a permanent assignment.

Companies with small engineering staffs are much less likely to hire new graduates. Instead, they tend to recruit engineers with at least some experience to meet immediate needs in specific functions or disciplines. Today, for example, the competition among small electronics companies for electrical or computer engineers with 2 to 10 years' experience is very keen, if not "cutthroat."

Smaller companies without formal employment departments are much more likely to use recruiting agencies to obtain experienced engineers. The newly hired employees are assigned at once to the projects for which they were hired.

Co-op Programs

Other things being equal, companies often prefer to hire new graduates who have spent work periods with them during a cooperative work-education, or co-op, program. A number of colleges and universities offer such programs. Typically, undergraduates spend alternate semesters in school and working full-time for companies that participate in the program. Other approaches are possible—in some programs, for example, students work half a day and attend school half a day.

During work periods, students have an opportunity to become familiar with individual companies and to learn something of the realities of engineering in industry. Companies, meanwhile, have an opportunity to observe prospective employees in a work setting. Thus, such programs provide financial support for students, important industrial-academic interchange, and sources of intermittent and ultimately permanent employees for industry.

Co-op programs require continuous commitments from both academic institutions and industrial participants to remain viable. Nevertheless, they are affected by national economic cycles. During periods of economic growth, co-op programs tend to expand with the needs of industry. During economic recession, on the other hand, the programs can suffer severely. Industrial practice during business downturns varies widely with respect to these programs. Some companies maintain co-op support levels for existing participants but curtail additions to the program. Others do not renew a co-op's contract upon completion of a work period. Still other companies cancel contracts before completion of a work period. All of these practices have negative effects on the participating students and academic institutions.

Properly managed co-op programs are valuable to both schools and companies and offer students a unique, work-related educational experience. Improperly managed programs suffer both short-and long-term damage.

THE STATE OF THE JOB MARKET

In the past few years there have been frequent reports of shortages of engineers, notwithstanding the dampening effect of the recession of 1981-1982. Actual shortages, however, appear to have been limited to certain specialties, such as electrical, electronics, and computer engineering. Some observers are concerned that shortages of engineers will persist beyond the near term, but the Bureau of Labor Statistics expects problems only in certain specialties involved in fast-changing technologies. On the whole, BLS projects an overall balance in supply and demand for engineers during the coming decade.[13] The BLS model, however, like others in the field, has shortcomings that reduce its reliability. It is based on a simple numerical balance and on current staffing patterns, which can change at any time. Further, the model does not consider the quality and level of degree attained, although these factors are highly relevant in the real case.

Impact of Government

The federal government has a major influence on supply and demand for engineers. Federal agencies directly employ about 100,000 engineers; the demand for engineers in several areas of the private sector depends heavily on the availability of federal contracts for research and development. Federal agencies also support engineering education, directly and indirectly, through a variety of mechanisms, including research contracts and grants, scholarships and fellowships, equipment and facility grants, and faculty incentive grants. Because of the impact of the federal government on the engineering profession, committee members studied the role of the federal government in the education and utilization of the engineer; that work is summarized in Appendix E.

Notes

1. *Science Indicators, 1982* (Washington, D.C.: National Science Board, 1983).

2. *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries: 1977-80* (Washington, D.C.: National Science Foundation, 1982).

3. *Engineering Manpower Bulletin*, March 1984 (New York: American Association of Engineering Societies).

4. *Ibid*., July 1984.

5. *U.S. Scientists and Engineers: 1980*. Surveys of Science Resource Series. NSF 82-314 (Washington, D.C.: National Science Foundation, 1982).

6. James E. Blackwell, *Mainstreaming Outsiders: The Production of Black Professionals* (Bayside, N.Y., General Hall, 1981).

7. *Engineering Manpower Bulletin*, December 1983 (New York: American Association of Engineering Societies).

8. *U.S. Scientists and Engineers: 1982*. Surveys of Science Resource Series. NSF 84-321 (Washington, D.C.: National Science Foundation, 1984).

9. J. W. Geils, "The Faculty Shortage: A Review of the 1981 AAES/ASEE Survey," *Engineering Education*, Vol. 73, No. 2, Nov. 1982, pp. 147-154; "The Faculty Shortage: The 1982 Survey," *Engineering Education*, Vol. 74, No. 1, Oct. 1983, pp. 47-53.

10. B. O. Weinschel, "Engineering Underutilization, Possible Remedies." Paper presented at the annual meeting of the American Society for Engineering Education, June 1984.

11. Committee on the Education and Utilization of the Engineer, *Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future* (Washington, D.C.: National Academy Press, 1985).

12. John B. Slaughter, *Science*, March 13, 1981, p. 1131.

13. *Labor-Market Conditions for Engineers: Is There a Shortage?* Proceedings of a Symposium (Washington, D.C.: Office of Scientific and Engineering Personnel, National Research Council, 1984).

Appendix A

Supplementary Data—Engineering Employment Characteristics

The following tables (A-1 through A-5) and figures [A-1 through A-14) provide supplementary data on engineering employment characteristics. Specifically, Tables A-1 through A-4 provide information on changes in the primary work activities of experienced engineers between 1972 and 1978, showing (in percentages) the flow of engineers into and out of management, production, R&D, and teaching. Table A-5 gives concentration ratios of engineers, engineering technicians, and computer specialists in major industries for 1960, 1970, and 1980.

Figures A-1 through A-7 show age distributions for engineers, by discipline, and for computer specialists; Figures A-8 and A-9 compare primary activities of all scientists and engineers as a group and of engineers in 1976, 1978, and 1980; and Figures A-10 through A-14 show concentration ratios of engineers, by discipline, in selected major industries for 1960 through 1978.

TABLE A-1 Changes in Primary Work Activity of Experienced Engineers: Flows Into/Out of Management, 1972-1978 (percent)

Discipline	In Manage merit, 1972	In Manage merit, 1978	Moved Into Management, 1972-1978	Moved Out of Management, 1972-1978
All engineers	22.9	32.8	18.5	8.6
Aeronautical	28.8	32.4	13.9	10.3
Chemical	18.1	31.7	20.2	6.6
Civil	33.4	42.3	20.5	11.6
Electrical	20.9	41.6	28.3	7.6
Industrial	26.4	37.7	22.7	11.4
Mechanical	20.2	31.5	18.7	7.4

SOURCE: Based on National Science Foundation data for experienced scientists and engineers (1972-1978).

TABLE A-2 Changes in Primary Work Activity of Experienced Engineers: Flows Into/Out of Production, 1972-1978 (percent)

Discipline	In Production, 1972	In Production, 1978	Moved Into Production, 1972-1978	Moved Out of Production, 1972-1978
All engineers	15.0	14.1	7.9	8.8
Aeronautical	7.4	7.3	4.4	4.5
Chemical	16.6	15.0	8.2	9.8
Civil	14.4	15.0	9.5	8.9
Electrical	5.4	5.5	7.1	7.0
Indus trial	24.6	23.6	13.5	14.5
Mechanical	4.4	3.2	6.7	7.9

SOURCE: Based on National Science Foundation data for experienced scientists and engineers (1972-1978).

TABLE A-3 Changes in Primary Work Activity of Experienced Engineers: Flows Into/Out of R&D, 1972-1978 (percent)

Discipline	In R&D, 1972	In R&D, 1978	Moved Into R&D, 1972-1978	Moved Out of R&D, .1972-197 8
All engineers	38.0	29.8	9.3	17.5
Aeronautical	43.7	42.7	15.5	16.5
Chemical	50.1	35.2	8.4	23.3
Civil	26.3	12.2	3.2	17.3
Electrical	42.9	37.7	10.7	15.9
Industrial	18.7	13.1	8.8	14.4
Mechanical	51.9	40.5	10.5	21.9

SOURCE: Based on National Science Foundation data for experienced scientists and engineers (1972-1978).

TABLE A-4 Changes in Primary Work Activity of Experienced Engineers: Flows Into/Out of Teaching, 1972-1978 (percent)

Discipline	In Teaching, 1972	In Teaching, 1978	Moved Into Teaching, 1972-1978	Moved Out of Teaching, 1972-1978
All engineers	2.4	2.3	.9	1.0
Aeronautical	1.1	1.5	.9	.5
Chemical	2.3	2.6	1.3	1.0
Civil	2.1	1.9	.6	.8
Electrical	3.6	3.5	1.1	1.2
Industrial	2.7	3.0	1.5	1.2
Mechanical	2.7	2.0	.4	1.1

SOURCE: Based on National Science Foundation data for experienced scientists and engineers (1972-1978).

TABLE A-5 Concentration Ratios of Engineers, Technicians, and Computer Specialists in Major Industries, 1960, 1970, and 1980 (in percent of total employment)

	Engineers			Technicians[a]			Computer Specialists		
Industry	1960	1970	1980	1960	1970	1980	1960	1970	1980
Primary metals	2.19	2.11	2.16	1.40	1.65	1.71	—	0.45	0.45
Fabricated metals	4.10	2.30	2.33	3.11	1.98	2.03	—	0.36	0.39
Chemicals	3.79	4.25	4.03	4.93	5.30	5.54	—	0.81	0.85
Communication	4.00	4.13	3.88	1.55	2.08	1.63	—	0.61	1.22
Machinery (except elec.)	4.20	5.19	4.80	2.97	3.05	2.98	—	1.78	2.30
Electrical machinery	6.97	8.02	7.10	5.07	4.74	5.03	—	1.20	1.31
Electronic computers	—	10.71	9.55	—	6.76	6.68	—	10.67	10.87
Professional and scientific equipment	6.66	6.32	6.08	5.39	4.31	4.85	—	1.17	1.39
Motor vehicles	2.49	3.03	3.75	1.79	1.66	1.46	—	0.56	0.59
Aircraft	12.64	14.31	15.68	4.97	4.29	4.22	—	2.24	2.66
Engineering services	27.07	26.73	25.24	20.50	25.09	18.80	—	0.75	1.12
Commercial R&D	—	15.01	12.74	—	17.98	14.71	—	3.78	4.17
Computer programming	—	3.77	2.48	—	1.77	2.58	—	26.44	25.35
Business management	—	6.47	1.28	—	1.78	1.07	—	3.73	2.13

[a] Includes both engineering and science technicians.
SOURCE: Bureau of the Census.

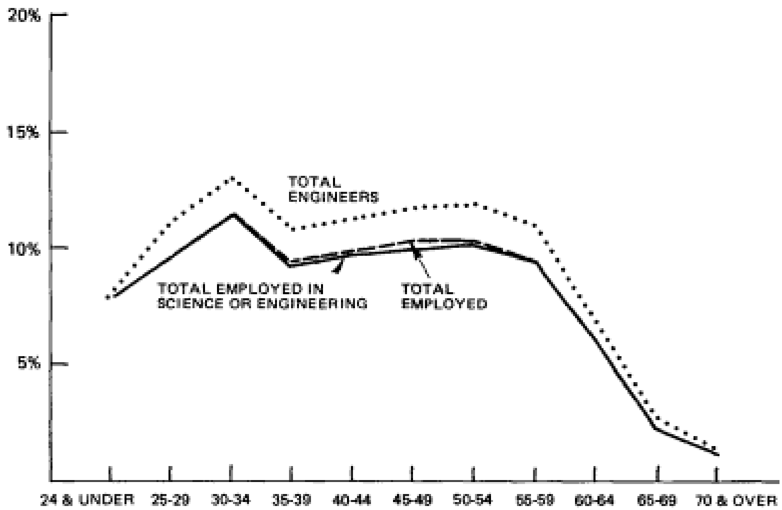

Figure A-1
Age distribution of aeronautical/astronautical engineers.
Sources: National Science Foundation, Bureau of the Census.

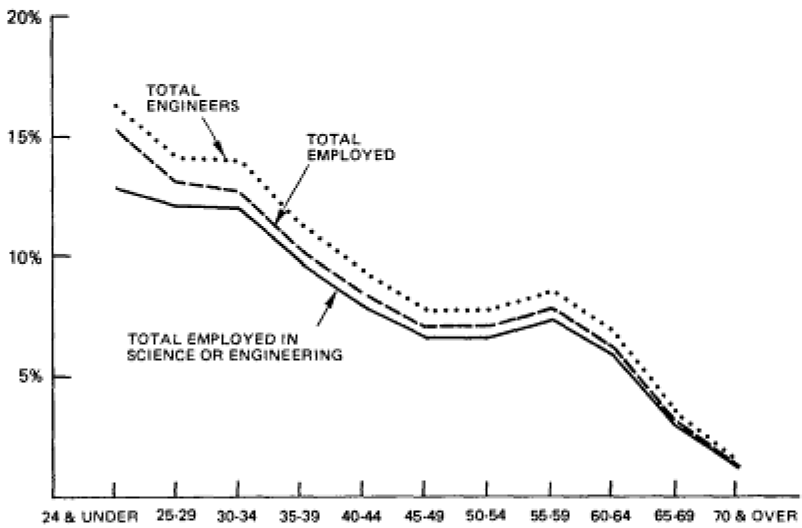

Figure A-2
Age distribution of chemical engineers.
Sources: National Science Foundation, Bureau of the Census.

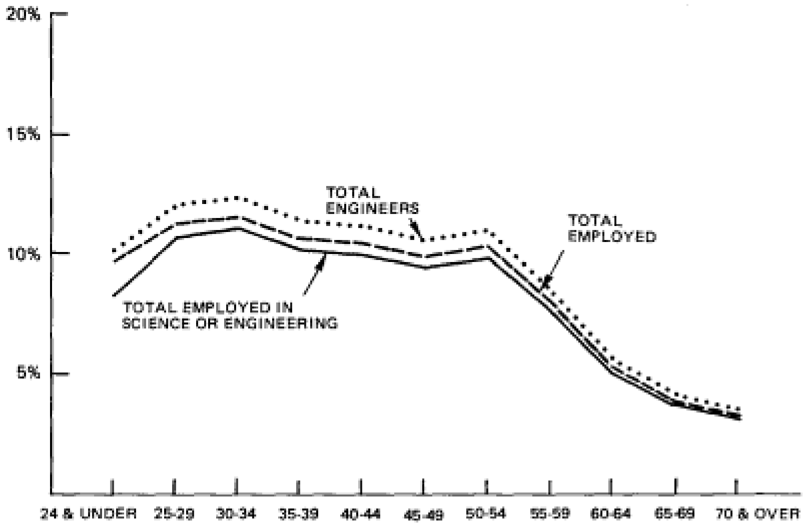

Figure A-3
Age distribution of civil engineers.
Sources: National Science Foundation, Bureau of the Census.

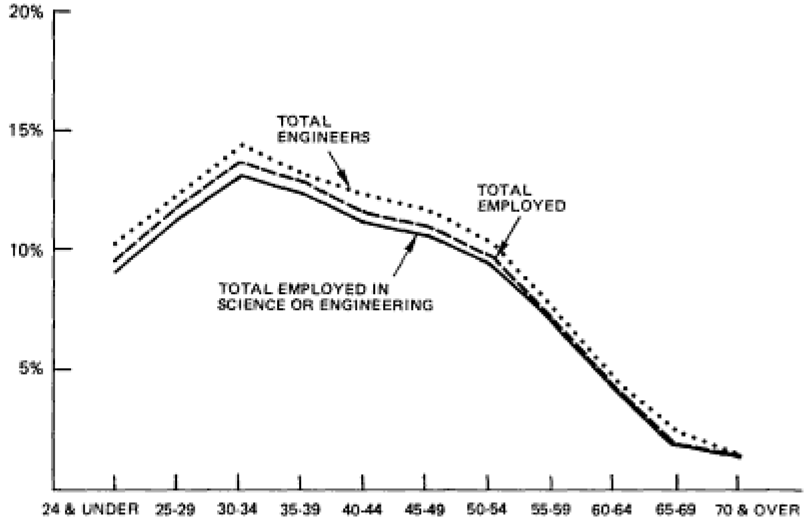

Figure A-4
Age distribution of electrical/electronic engineers.
Sources: National Science Foundation, Bureau of the Census.

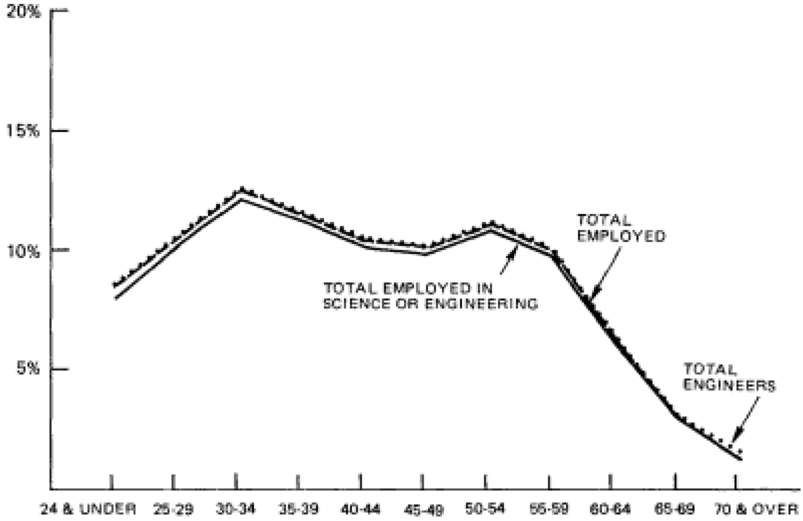

Figure A-5
Age distribution of mechanical engineers.
Sources: National Science Foundation, Bureau of the Census.

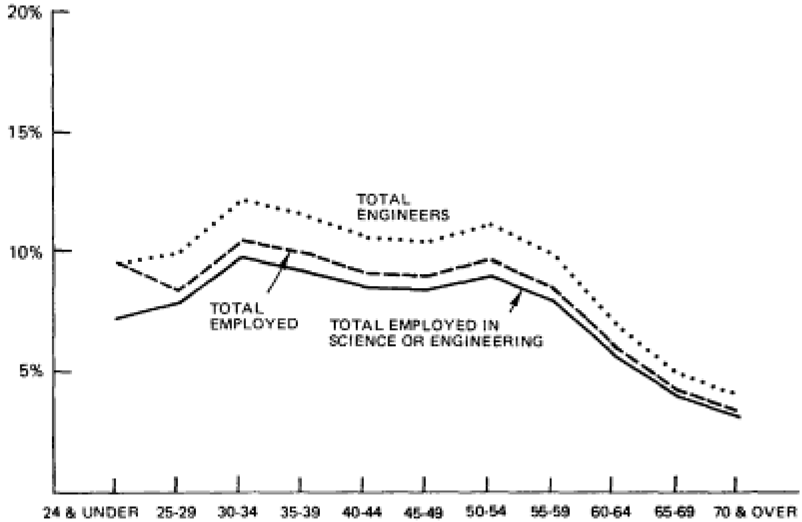

Figure A-6
Age distribution of other engineers.
Sources: National Science Foundation, Bureau of the Census.

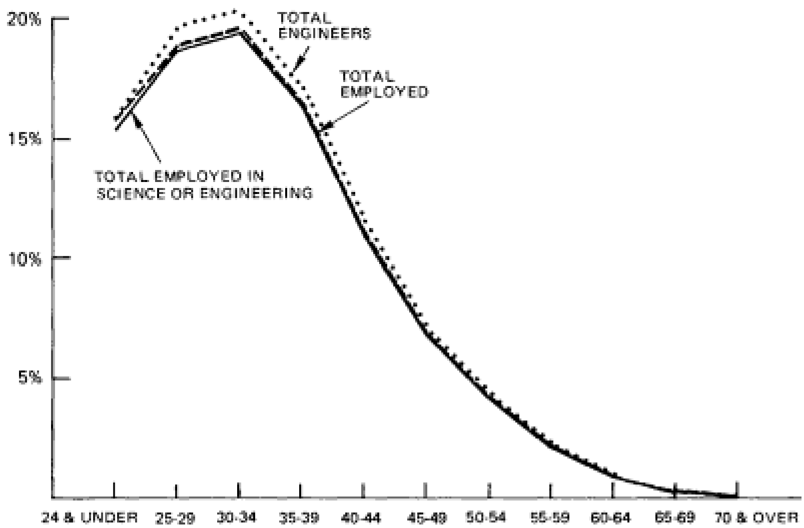

Figure A-7
Age distribution of computer specialists.
Sources: National Science Foundation, Bureau of the Census.

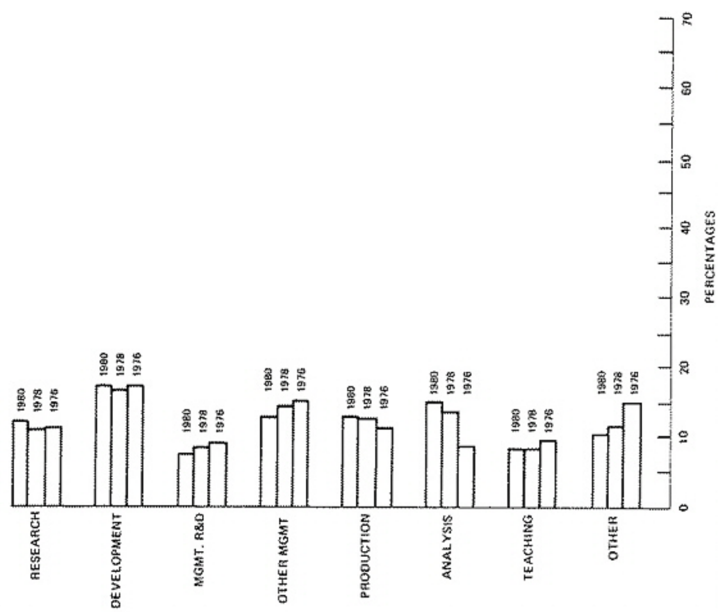

Figure A-8
Comparison of primary activity, by year, all fields of science and engineering.
Source: National Science Foundation.

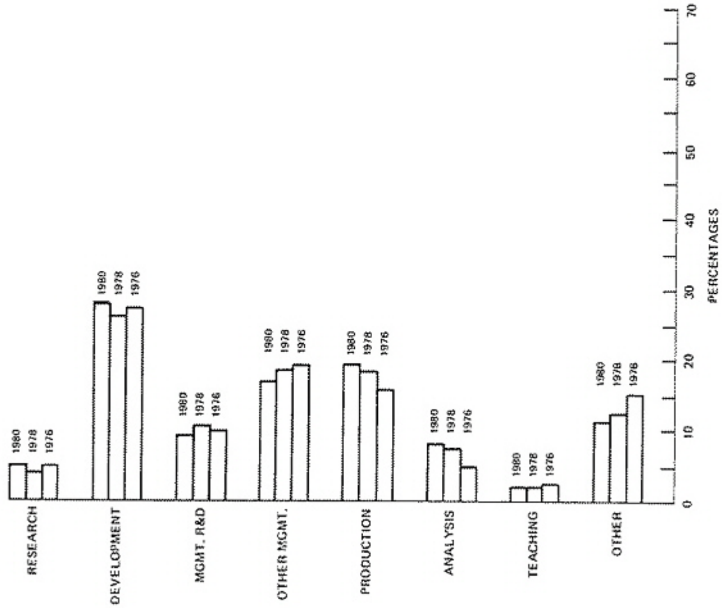

Figure A-9
Comparison of primary activity, by year, engineers.
Source: National Science Foundation.

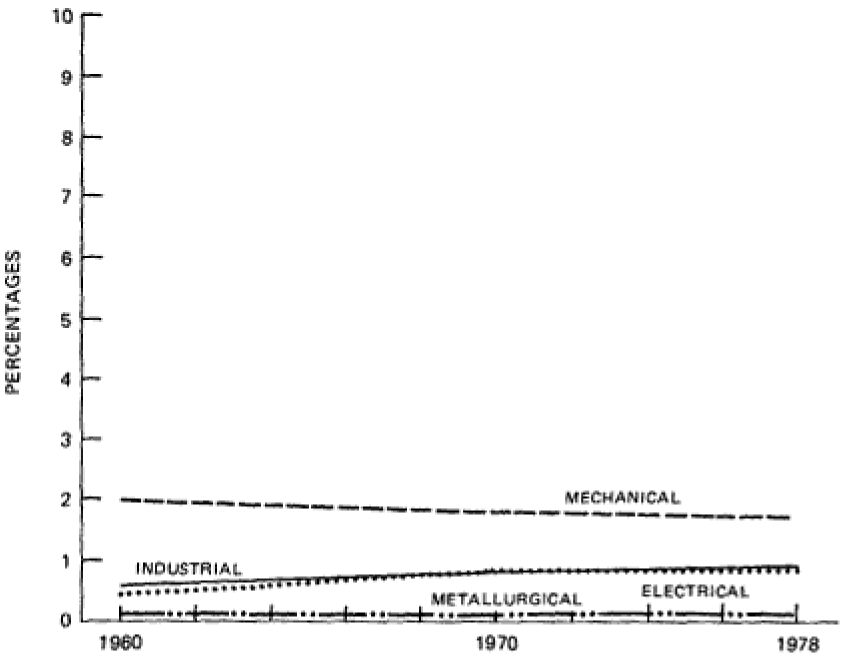

Figure A-10
Concentration ratios of engineers in machinery (except electrical) industry, 1960-1978.
Sources: BLS Occupation/Industry Matrices, 1960, 1980, 1978.

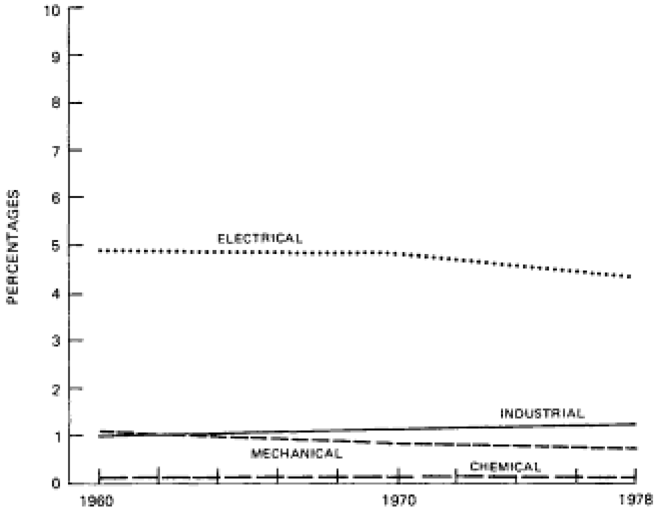

Figure A-11
Concentration ratios of engineers in electrical machinery industry, 1960-1978.
Sources: BLS Occupation/ Industry Matrices, 1960, 1970, 1978.

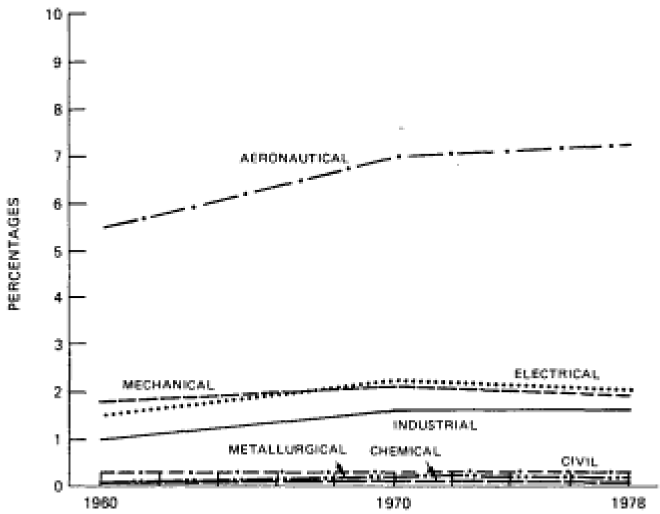

Figure A-12
Concentration ratios of engineers in aircraft industry, 1960-1978.
Sources: BLS Occupation/Industry Matrices, 1960, 1970, 1978.

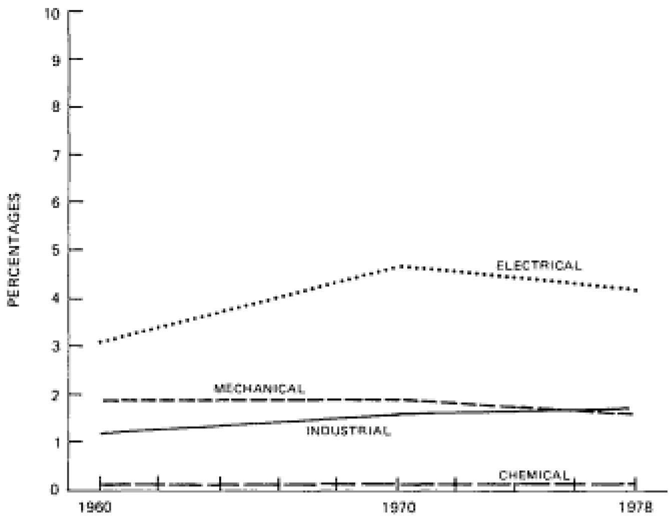

Figure A-13 Concentration ratios of engineers in electronic computing industry, 1960-1978.
Sources: BLS Occupation/ Industry Matrices, 1960, 1970, 1978.

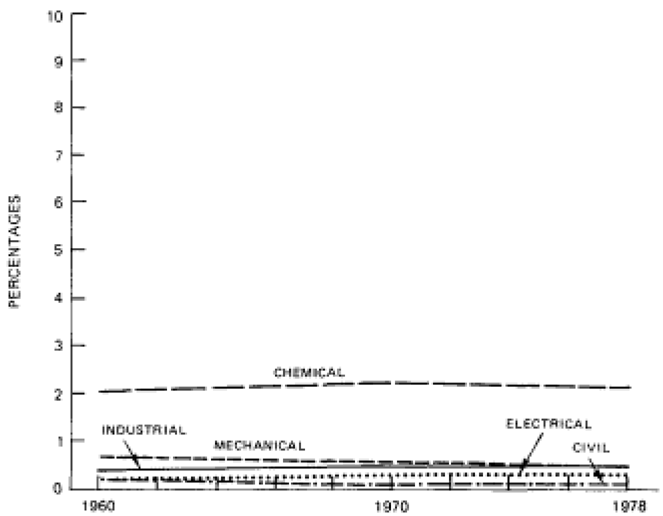

Figure A-14
Concentration ratios of engineers in chemicals industry, 1960-1978.
Sources: BLS Occupation/ Industry Matrices, 1960, 1970, 1978.

Appendix B

Women in Engineering

Helen Gouldner

The decade of the seventies was witness to a remarkable influx of women into the engineering profession.[1] The proportion of women of the total earning bachelor's degrees in engineering grew from 0.83 percent in 1970 to 9.70 percent in 1980. A contrast of the raw numbers at the beginning or the end of this period highlights the extent of this evidence: there were only 358 women graduated in 1970, compared with 5,631 in 1980. The upward trend continued with the graduation of 6,357 women in 1980 and 8,140 in 1982. This meant that women were awarded 12.15 percent of the total number of bachelor's degrees in engineering in 1982, compared with 1.19 percent a decade earlier.

However, according to the statistics gathered by the Engineering Manpower Commission, there may be a leveling off of the entrance of women into engineering programs. Although the enrollment of freshman women had increased 14 percent during the year 1981, it dropped to a 3 percent increase in 1982. Since this constituted a much lower rate than the increase in upper-class enrollment of women in engineering majors, it is difficult to assess the reasons for the decline. With the demand for women engineers remaining high and the starting salaries for engineering graduates outpacing other fields, the freshman enrollment dip may be only a temporary blip on the charts.

It was estimated by the National Science Foundation that the total

Helen Gouldner is a member of the Panel on Engineering Employment Characteristics. This appendix was prepared in April 1984.

number of engineers in the United States was 1,387,000 in 1980. Of the 34,850 women in this population, 32,600 are employed as engineers mainly in business and industry (76.4 percent), with the greatest concentration in civil engineering (12 percent).[2] Women are also employed in the specialties of chemical (11.0 percent), electrical/electronic (11.7 percent), and mechanical (11.7 percent) engineering. As compared with men, the highest proportion of women is in the field of chemical engineering (5 percent), or 3,600 out of a total of 72,400 chemical engineers in the work force.

The Society of Women Engineers (SWE) was founded in 1950 by women engineers to inform the public about the achievement of women engineers and to encourage young women to choose engineering as a profession. In 1961 SWE established a center for information on women in engineering. In cooperation with other engineering associations, it played a role in disseminating information about careers in engineering and supported promising women with scholarships.

The SWE tried to combat a number of mistaken ideas about the field of engineering that might discourage women from entering an engineering career.[3] A number of widely held beliefs about engineering, the society pointed out, are myths and outdated stereotypes. Among these notions about engineering that may deter women from selecting engineering as a field of study are the following:

- That engineers work mainly with *things* rather than *people*. Untrue.
- That girls play less with mechanical toys and engines in childhood and adolescence than boys. True.
- That those early interests and hobbies are related to success in engineering. Untrue.
- That engineering students must sacrifice their social life at college to the demands of their course work. Untrue.

Once women enter engineering careers, what are their prospects for advancement? Asked this question, a president of SWE who is a leading instrumentation engineer drew on her experience in industry since her graduation as a mechanical engineer in 1950. She was asked if women engineers face different problems in the 1980s than in the 1960s. Her response was:

I don't see much difference between 1960 and 1980, although the growing number of women will enhance the possibilities for women making it. . . . **I** think there will still be the struggle to get into senior management, but more women will be given the chance to try. . . . It will probably take about ten years for senior management to reflect the number of women now in engineering. . . .

Today it is still difficult for women to move up in engineering in many organizations. But with the increase in their numbers, more women should get into middle and upper management. The growing number of women engineers will also act as role models providing incentive and motivation to young female engineers.[4]

NOTES

1. United States Department of Education. Engineering Manpower Commission Surveys, 1967-1982.
2. National Science Foundation. *U.S. Scientists and Engineers, 1980* (Washington, D.C., 1982).
3. Engineers' Council for Professional Development. "Engineering—A Goal for Women." EC-92(3), August 1979.
4. Ann Seets-Petrack. "Straight Talk." Interview with Ada Pressman. *Graduating Engineer*, Spring 1980, pp. 23-26.

Appendix C

The Social Context of Minorities in Engineering

Helen Gouldner

Until recently, the engineering profession was an occupation in which American minorities—those who were black, Chicano, Puerto Rican, and American Indian—were grossly underrepresented. Twenty-five years ago, only 2.8 percent of the engineers in the United States came from these four groups, although at that time they constituted 14.4 percent of the population of the country. In the ranks of the 43,000 American students graduating as engineers in 1971, only 407 were black—and a sprinkling were from the other minorities. This meant that graduates of minority backgrounds made up about 1 percent of the engineering class of that year. It was clear that these minorities were not making progress in entering the mainstream of the American occupational structure through the technical and engineering professions that are so important in the backgrounds of many corporate and research leaders. It was also evident that the potential for increasing the much-needed supply of well-trained engineering personnel lay in the virtually untapped human resources of the minority communities.

Blacks, Hispanics, and American Indians faced particular cultural and social barriers to reaching the level of academic attainment required of science and engineering professionals. In the classic study of the American occupational structure published in 1967, Blau and Duncan pointed out that minorities were required to make many more sacrifices to stay in school but were much less motivated than majority

This appendix was prepared in May 1984.

students by the job prospects open to them.[1] Spurred on by the civil rights movement of the 1960s, the affirmative action legislation and programs of the 1970s, and the joint efforts of the private business sector and minority organizations, moves to open up new educational and occupational opportunities to hitherto neglected and excluded minorities were undertaken in a variety of ways.

In the field of engineering education, it was the engineering profession itself—at the initiative of some of its forward-looking industrial and academic leaders—which not only made a commitment to increasing the supply of minority engineering graduates but also followed through with bold and sustained planning and financial support for programs to matriculate and graduate a larger number of minority engineers annually. The National Action Council for Minorities in Engineering (NACME) was established and funded by corporate donations to carry out this mandate and to cooperate with others concerned with the education of minority engineers. After a decade it was notable how much had been achieved through the following: presentation of the "engineering story" to young people unfamiliar with the profession; early recruitment and guidance in high schools; precollege summer institutes; financial assistance to able students; special monitoring programs, including remedial work; social support systems for racial minorities and on-going consultation with engineering schools and minority engineering program directors; and research on problems remaining to be solved in minority engineering education. As a result of these activities, substantial gains in the enrollment and graduation of minorities in engineering took place. By 1982, for example, 3,500 blacks, Hispanics, and American Indians were graduated in engineering compared with 1,300 in 1973. Moreover, freshman minority enrollment in engineering schools had tripled, and the total number of minority undergraduates had risen to 32,000 from the 8,500 levels of the previous decade.

In assessing the strategies for recruiting and graduating an increasing number of minority engineers, we need to take into account some general social and cultural conditions impinging on the successful outcome of the efforts.

PERSISTENT EDUCATIONAL DISADVANTAGES OF MINORITIES

Attrition disproportionately reduces the number of blacks, Hispanics, and American Indians in the school system at every level.[2] For example, at the point of high school graduation, roughly one-third of the black students and almost one-half of the students from the other two groups have dropped out of school. Although it is true that those minority students (except for American Indians) who finish high school go on to college in approximately the same proportions as their white counterparts, they do not fare as well in graduating from four-year colleges. Whereas about 60 percent of the white students earn their degrees, the college completion for blacks is 41 percent, and for Chicanos, Puerto Ricans, and American Indians, approximately 30 percent. Thus, both at the time of entry into college programs and at the point of graduation, there is a significant reduction in the potential supply of minorities entering the occupational structure on a professional level.

The scarcity of minority engineers, then, must be seen in the context of the differences in overall educational participation and achievement of minorities inasmuch as the recruitment of minorities into engineering is necessarily affected by their numbers in the pool of high school graduates. Moreover, the lower educational level of the parental generation plays an important role in the guidance minority students receive to prepare for college entrance. Minority students whose parents have not attended college are less likely to take the necessary mathematics courses in high school which would provide the foundation for pursuing a bachelor's degree in engineering.[3]

THE LEGACY

The enrollment of minorities in white universities—in which virtually all of the engineering schools are located—is of recent origin. Thirty years ago, around 90 percent of the black students were registered in predominantly black institutions; now roughly three-fourths of them attend white colleges and universities. The literature suggests that most of these students expressed high hopes that they would be less apt to experience discrimination in a university setting, yet many perceived they had been rebuffed or misunderstood and felt isolated and rejected.[4] The special needs for social support felt by minorities in engineering programs, especially in schools with low minority enrollment, were noted by NACME in considering the ways to help keep minorities in school through graduation. It was suggested that Hispanic, American Indian, and black student organizations are able to provide not only peer support but to serve as "culture shock absorbers" to offset any negative psychological effects on their academic performance that is derived from a sense of social and cultural isolation.

It is worth remembering that the professions that were traditionally entered by minorities were those in which it was possible to work in the minorities' own communities. It was said that they chose to "serve their own and practice alone"—first in preaching and teaching and later in medicine and law. Moreover, these occupations could be conducted independently of outside controls. As minority professionals have become more generally included in every kind of American enterprise, however, they work alongside some colleagues who are still intolerant of racial and cultural differences. Although a majority of minority professionals have learned to function relatively well in these settings, it has meant that many of them have been compelled to "commute psychologically" between the world of work and their home base.[5] In the cases of the minority engineers now employed by American businesses, they should be the indirect beneficiaries of the entrance of more minority engineers into the work force. Undoubtedly, as the numbers of minority engineers increase, the strain on the numerically rare—"tokens"—should be relieved.[6]

NOTES

1. Peter Blau and Otis Dudley Duncan. *The American Occupational Structure* (New York: Wiley, 1967).

2. Commission on the Higher Education of Minorities. *Final Report*. (Los Angeles: Higher Education Research Institute, 1982).

3. Sue B. Berryman. Who *Will Do Science?* (Rand Corporation, 1984).

4. W M. Boyd. *Desegregating America's Colleges* (New York: Praeger, 1974)

5. Adelbert Jenkins. *Tile Psychology of the Afro-American* (New York: Pergamon, 1982).

6. Rosabeth Moss Kanter. *Men and Women in the Corporation*. (New York: Basic Books, 1977). *See* Chapter 8, "Numbers: Minorities and Majorities."

Appendix D

Informal Mail Survey of Employers of Engineers

Following are the questionnaire and a summary of the results of the informal mail survey of employers of engineers conducted by the Panel on Engineering Employment Characteristics. Of the approximately 350 firms to which the panel sent the survey (scientific sampling procedure was not employed), 107 firms responded.

FORM USED IN MAIL SURVEY

Information Prepared by:

1. Name ______
2. Position and Organization ______ } Optional
3. Division or Company ______

4. Number of Employees in Division or Company ______
5. Number of Engineering Employees Reported on ______
6. Major Products/Services of the Division or Company ______

Field	Total Number Included	Average Number of New Graduates Hired/Year (last 3 years)
Computer Hardware		
Computer Software		
Aeronautical Engineer		
Chemical Engineer		
Civil Engineer		
Electrical Engineer		
Electronic Engineer		
Industrial Engineer		
Mechanical Engineer		
Other Engineer		
Mathematician		
Physicist		
Chemist		

NOTE: This information is required so that data can be properly identified as to industry (academic) sector for comparison with other sectors.

	Education Level Desired B.S., M.S., Ph.D.		Utilization of Technical and Problem-Solving Skills 1. Fully utilized 2. Somewhat underutilized 3. Very underutilized Years From Initial Employment		Will This Field 1. Increase 2. Stay the same 3. Decrease in Importance to Your Company in the Next 5 Years?	Difficulty Finding Recent Quality Graduates 1. Very difficult 2. Somewhat difficult 3. Not difficult	Trend in Quality of Recent Grads in Last Five Years 1. Rapid increase 2. Increase 3. No change 4. Decrease 5. Rapid decrease
Field	Entry Level	Managers	Less than 5	Over 10			
Computer Hardware							
Computer Software							
Aeronautical Engineer							
Chemical Engineer							
Civil Engineer							
Electrical Engineer							
Electronic Engineer							
Industrial Engineer							
Mechanical Engineer							
Other Engineer							
Mathematician							
Physicist							
Chemist							

	A. How widely are these available in your organization? 1. Widely available 2. Limited availability 3. Not available	B. What is the investment *per engineer* in these tools? $/ affected engineer	C. Have you formally evaluated the impact of tools on engineering/scientific productivity?* 1. Yes 2. No	D. What is your estimate of the impact of these tools on engineering and scientific productivity? Percent improvement in *individual* productivity
Computer-aided drafting				
Computer-aided design				
Computer-aided manufacture				
Access to computer-based engineering information systems				
Others (please specify)				
1.				
2.				
3.				

* If yes, please attach copies of any available documents.

RESPONSES TO INFORMAL SURVEY

TABLE D-1 Survey Responses Regarding Difficulty in Finding Quality Graduates

Engineers	Percent Responding "Very or Somewhat" Difficult	Number of Respondents
Computer hard-ware	67.5	37
Computer soft-ware	52.8	53
Aeronautical	25.0	16
Chemical	33.4	39
Civil	14.0	57
Electrical	58.2	67
Electronic	65.7	35
Industrial	33.4	36
Mechanical	47.4	76

TABLE D-2 Survey Responses Regarding Utilization of Engineers

Engineers	Percent Fully Utilized	Number of Respondents
Computer hard-ware	75.0	40
Computer soft-ware	73.7	57
Aeronautical	43.8	16
Chemical	37.2	43
Civil	70.5	61
Electrical	60.0	75
Electronic	45.9	37
Industrial	45.0	40
Mechanical	55.4	83

TABLE D-3 Survey Responses Regarding Impact of New Tools on Engineering Productivity

A. Computer-aided drafting:

31% had widely available systems; 27% had no system.
Systems cost approximately $10,000 per engineer affected.
46% had formally evaluated their systems.
Average increase in productivity of those affected was estimated to be 100%.

B. Computer-aided design:

33% had widely available systems; 27% had no system.
Systems cost approximately $7,000 per engineer affected.
40% had formally evaluated their systems.
Average increase in productivity of those affected was estimated to be 50%.

C. Computer-aided manufacturing:

Few systems are in place.

D. Engineering information systems:

49% had widely available systems; 18% had no system.
Systems cost approximately $3,000 per engineer affected.
24% had formally evaluated their systems.
Average increase in productivity of those affected was estimated to be 35%.

Appendix E

Report on the Role of the Federal Government in the Education and Utilization of the Engineer

W. Edward Lear and Donald G. Weinert

Almost every agency of the federal government has some involvement in the education and utilization of engineers in the nation, and several play a major role.

With respect to utilization, federal agencies employ approximately 100,000 engineers in their various headquarters offices, branch offices, and laboratories. However, the federal influence on the engineering labor market goes far beyond direct employment of engineers in government installations. The demand for engineers in several private-sector areas depends heavily on the availability of federal contracts for development and research. The National Aeronautics and Space Administration (NASA) cutback of more than a decade ago still serves as a strong reminder of the disruption that can occur in engineering employment following a sudden change in federal spending priorities.

Direct and indirect support of engineering education by federal agencies had taken a variety of forms—research contracts and grants; student scholarships, fellowships, and work-study programs; job and guaranteed loans; equipment and facility grants; summer or longer-term employment of faculty in government laboratories; curriculum development grants; funding of specialized research and training institutes; travel grants; faculty incentive grants; and specialized studies of various facets of the engineering education system.

W. Edward Lear and Donald G. Weinert are members of the Committee on the Education and Utilization of the Engineer. Appendix E was completed in May 1984.

Following is a compilation of available data on the employment of engineers and support of engineering education by the federal government.

EMPLOYMENT OF ENGINEERS

The most recent data available (1981) on federal employment of engineers that include all the major agencies are shown in Table E-1.

The U.S. Department of Defense (DOD) is seen to be by far the largest employer. About one-fourth (14,500) of DOD engineers are employed in the various laboratories of the department. Among laboratory engineering employees, electrical/electronic engineers are the predominant disciplinary group, as shown in Table E-2.

As stated earlier, the impact of the federal government on engineering employment is indicated only partially by the direct employment statistics for the various agencies. The Department of Defense, for example, has a large and growing influence on engineering manpower demand through its multitude of contractors and subcontractors. It is estimated[1] that, in addition to the numbers shown in Table E-l, another 13 percent of the total science and engineering work force in the nation is linked to DOD budgets and programs. This can be translated into numbers of engineers involved by noting that of the approximately 2.9 million scientists and engineers in the nonfederal work force, about 48 percent are engineers. The result is that roughly 181,000 nongovernment engineers depend on DOD for employment.

There are obviously other agencies that substantially influence the engineering labor market beyond direct employment of engineers in civil service positions. Unfortunately, reliable figures are not available on their total impact on engineering employment, but it is clear that for those agencies that have a prime technological mission and which have substantial research and development contracts with the private sector, indirect engineering employment far exceeds direct employment. For example, the Department of Energy has 2,813 civil service engineering employees (Table E-l), but estimates that another 10,000 to 11,000 engineers are employed in its contractor-operated laboratories alone. And the National Aeronautics and Space Administration, which is second only to DOD in direct employment of engineers, has an estimated 50,000 non-civil service engineering positions tied to its research and development contracts.

Based on the 1981 data, therefore, the number of engineering employees partially or totally supported by the federal government was not simply the 91,000 civil service positions listed in Table E-l, but probably totaled more than 300,000 in direct and indirect employment just for the three agencies for which some estimates are available.

A different approach to the determination of the federal role in engineering employment is available through the 1982 "postcensal" data collected by the National Science Foundation, as shown in Table E-3. These data represent responses from what is purported to be about one-half of the nation's engineers to the question of whether the individual's job is supported, either partially or totally, from federal sources.

The first panel of Table E-3 provides the summation of responses from all engineering disciplines. Of the 1.05 million engineers who responded, 29 percent (301,000) stated that they had federal support. (An interesting sidelight in these figures is that if these are truly the responses from about half of the nation's engineers, the total engineering work force would be nearer 2 million rather than the 1.3 million figure frequently used.) It is apparent, too, from Table E-3 that there are other agencies (Department of Transportation and Environmental Protection Agency) besides DOD, the Department of Energy (DOE), and NASA that have a significant effect on non-civil service engineering employment.

There is an obvious discrepancy in the absolute number of engineering jobs with federal support indicated by the two approaches. The figure of approximately 300,000 positions obtained from the 1981 data reflected in Tables E-1 and E-2 includes only three agencies and depends heavily on agency estimates of contractor jobs supported. It also assumes a total science and engineering work force of 2.7 million, of which 48 percent (1.29 million) are engineers. The postcensal data, on the other hand, depend on responses of individual engineers (or those who class themselves as engineers), and there are obvious questions raised regarding the accuracy of response when we note (Table E-3) that only 94 percent of federal government engineers and 84 percent of military/commissioned corps engineers reported federal support for their jobs. In any event, the postcensal data indicate that the absolute number of engineers employed in jobs partially or totally supported by the federal government is about 600,000, assuming that the 301,452 positions shown in Table E-3 are the response from half the engineering work force and represent the situation in the total work force.

In summary, although there is uncertainty regarding the absolute number of engineering jobs with federal support, it seems reasonable to believe that the percentage of such jobs reported by engineers in the postcensal survey is approximately correct. That figure is 28.7 percent (301,452,/1,050,872, Table E-3) and suggests that there are 373,100 federally supported engineers if the work force totals 1.3 million, and

574,000 if the engineering work force is 2.0 million. In either case, the federal influence is substantial. Table E-3 also details the postcensal data for the individual engineering disciplines.

SUPPORT OF ENGINEERING EDUCATION

Research

The federal government has obligated an estimated $3.487 billion for basic and applied research in engineering for Fiscal Year (FY) 1984. Of this amount, $446 million is for engineering research carried out in colleges and universities. For FY 1982, the last year for which actual expenditures rather than estimates are available, the comparable figures are $3.386 billion and $361 million. Levels of support by agency and by engineering discipline for university-based basic and applied engineering research are shown in Tables E-4 through E-7.

A very sizable difference exists between the data collected from grantors and grantees. Tables E-4 through E-7 show dollars obligated for engineering research in universities as reported by the various agencies and tabulated by NSF. An analogous survey is conducted annually by the American Society for Engineering Education (ASEE), in which the engineering colleges report an al research expenditures broken down by source of support. Figures for the federal FY 1983 and for the 1982-1983 university year should be comparable, but the sum of basic and applied research support for FY 1983 as given in Tables E-4 and E-6 is $389 million, while the engineering colleges report in the ASEE survey[2] an expenditure in 1982-1983 of $ 761 million from federal government sources. The most probable reason for this $372 million difference is that many engineering schools are reporting under research expenditures work that is classified as development in the NSF reporting. The total federal support for development projects in universities in FY 1983 is estimated at $589 million, and it seems reasonable to expect that a substantial fraction of this is done in the colleges of engineering.

Financial Aid

A rough estimate of the amount of federal financial aid going to engineering undergraduate students is obtained starting with the current fraction of engineers in the total undergraduate population of the nation, or 415,000/12,400,000 = .0335. Total student aid in the universities was $7.7 billion[3] in 1982-1983, and approximately half ($3.85 billion) of this came from federal sources. Assuming that engineering students receive financial aid in the same proportion as other undergraduates gives a figure of $129 million for the engineers. This appears to be a large amount but averages out to only $620 from federal sources per engineering aid recipient, making the further assumption that engineering follows the pattern of all undergraduates, in which roughly half the students have some form of financial aid.

Another form of aid to undergraduate students in engineering is the support of a substantial number of undergraduate research assistants by federally funded research contracts and grants in the engineering colleges. The amount of this support is not available and lies embedded in the figures given earlier for support of engineering research and development in the universities.

Graduate Fellowships

Several federal agencies provide competitive fellowships for graduate students in engineering. The fellowships provide an annual stipend for the student, usually renewable for three years, plus an institutional allowance and/or tuition.

The major federal engineering graduate fellowship programs are shown in Table E-8. In several cases the numbers shown are for the engineering portion of a larger science and engineering program. In the NSF program, for example, engineering students were awarded 112 of the 600 fellowships currently available. The NASA program provides three-year support and adds 40 new fellows each year for a total of approximately 120 students in the program at one time. Of that total number, 36 are engineers. In contrast, in the Navy [Office of Naval Research [ONR]) program, 66 of 80 current fellowship holders are engineers.

The numbers of fellowships and stipend levels indicated in Table E-8 are for early 1984. Thirty-two new students will be added to the Navy (ONR) program in the fall of 1984 for a total of 112. NASA has plans to add 80 new fellows per year rather than 40, although most of these will be in the sciences as a part of the space platform effort. Both NASA and NSF plan some increase in the stipends awarded during the coming fiscal year.

It should be noted that the 417 fellowships shown in Table E-8 are not the total effort of the federal government in support of engineering graduate students. Most of the federal contracts and grants for engineering research in universities have provisions for the employment of graduate students as research assistants. The number of engineering students supported in this fashion is not available, but an estimate can be made using data available in the 1982-1983 ASEE survey[4] of engineering college research and graduate study. The survey shows that 65 percent of the research support of the engineering colleges came from the federal government and that 25,484 graduate students were involved in research supported from all sources. Assuming students were employed on the research projects in proportion to dollars available gives an estimated 16,600 graduate research assistants with federal government support.

Also involved in engineering research at universities are postdoctoral fellows, although postdoctoral appointments are not nearly as common in engineering as in the sciences. The ASEE survey for 1982-1983 lists 862 postdoctoral fellows engaged in research. Again, assuming that 65 percent of this number have federal support (a number that is probably low) gives an estimated 560 postdoctoral appointees. Since these engineers are almost all supported from research contracts and grants, the federal dollar involvement is included in the research figures quoted earlier. An estimate of the amount devoted to postdoctoral appointees can be obtained from data collected by NSF on postdoctoral student employment by its engineering research grantees. In FY 1983 there were 155 postdoctoral employees working for varying lengths of time on NSF grants at a total cost of $1.75 million. This gives an average cost per employee of $11,300 and translates to $6.3 million of support for the 560 postdoctoral appointees estimated to be employed on engineering college research contracts and grants from federal agencies.

Equipment

Obsolescence of undergraduate instructional equipment for engineering is a critical issue that is not being addressed by the federal government. The modest NSF program of matching grants for instructional equipment was phased out in 1981, and plans to revive it are tenuous. There is, however, an effort to address the shortage of research laboratory equipment in some areas, and both DOD and DOE have initiated programs that provide equipment for science and engineering in research areas which support the missions of the agencies. The DOE program is funded at $4 million in FY 1984 and will increase to $6 million in FY 1985. Awards are only available to researchers who currently have at least $150,000 in DOE research support, and the equipment to be purchased must cost at least $100,000. The DOD program provided $30 million for research equipment in selected areas in FY 1983, and an additional $60 million has been awarded to university researchers for the two-year period, FY 1984 and FY 1985. There is unfortunately no information available on the fraction of the money in either of these programs that was awarded to engineering. A listing of the eligible research areas would suggest, however, a reasonable guess that half of the money was awarded for the purchase of engineering research equipment. Under this assumption engineers received from the two agencies $15 million in FY 1983, $17 million in FY 1984, and will receive $18 million in FY 1985 for the purchase of research equipment.

Research equipment can, of course, be purchased as a part of the research and development grants and contracts of many agencies. For example, DOD now allows up to 10 percent of a research contract amount to be spent for equipment, and NSF anticipates an expenditure of approximately $17 million (about 14 percent of the NSF engineering research budget) for this purpose in FY 1984 as a part of the grants made to universities for engineering research. This latter figure, incidentally, compares with $8 million in FY 1983 and represents a conscious effort by NSF to improve the research equipment base of the engineering colleges.

Continuing Professional Development

Federal civil service regulations provide for federal agency support for continuing professional development of engineers directly employed by the federal government. Activities under these regulations occur in two major categories: (1) support for attendance by federal employees at professional meetings and for participation in other activities of professional and technical engineering societies; and (2) support for participation in continuing-education activities, including technical seminars, short courses, and degree-producing courses. Continuing-education programs include both those presented by universities and technical engineering societies and those presented by the federal agencies themselves.

The level of resource commitment by the federal government to continuing education of its engineering employees is probably very substantial. Unfortunately, however, the system is so decentralized that no reliable data are available.

Summary of Direct Support

A summary of the estimated major direct support of engineering education by agencies of the federal government is given in Table E-9.

In addition to the various forms of direct support for engineering education that have been discussed above, the federal government spends an undetermined amount for what can be classified as indirect support. A leading program in this category is provision by the various agencies of short-term employment of faculty members in research laboratories. Perhaps the largest of these is the NASA summer faculty fellowship program, which brings to NASA laboratories each year about 300 faculty members, approximately 120 of whom are engineers. Similar programs of the Navy, Air Force, and Department of Energy involve a total of 50 to 75 engineers each summer, depending on the disciplinary distribution of applicants. Total government cost of the engineering part of these four programs for the summer months is in the range of $1.5 million. The Army also employs faculty members for short consulting assignments, usually a few months to a year in duration, as do a number of other government agencies. Unfortunately, no figures are readily available for the total engineering involvement or the amounts expanded.

Finally, federal funds for construction of university facilities for engineering and science (e.g., NASA space sciences buildings) have been available at times in the past, but have essentially disappeared from the scene today.

NOTES

1. Report of the DOD-University Forum Working Group on Engineering and Science Education, July 1983.
2. *Engineering Education*, vol. 74, no. 6, March 1984.
3. *Higher Education and National Affairs*, American Council on Education, April 9, 1984.
4. *Engineering Education*, vol. 74, no. 6, March 1984.

TABLE E-1 Total Number of Engineers Employed by the Federal Government, by Agency (1981)

Agency	Number
Total	90,914
U.S. Department of Defense	56,473
Veterans Administration	992
U.S. Department of Agriculture	3,306
U.S. Department of Health and Human Services	473
U.S. Department of the Interior	3,058
National Aeronautics and Space Administration	8,819
U.S. Department of Commerce	748
U.S. Department of Transportation	4,653
U.S. Department of Energy	2,813
Environmental Protection Agency	1,618
Tennessee Valley Authority	3,922
Other	4,038

NOTE: Data indicate full-time permanent employees only.

SOURCE: National Science Foundation, Division of Science Resources Studies.

TABLE E-2 Number of U.S. Department of Defense Laboratory Scientists and Engineers, by Discipline, September 30, 1981

	Civilian	Military
Engineers		
Electrical/electronic	5,916	256
Mechanical	2,663	283
Aeronautical	1,364	250
General	1,893	18
Other	1,661	199
Total engineers	13, 497	1,006
Scientists		
Physics	3,303	} 364
Chemistry	1,198	
Math/statistics	1,931	} 10
Computer science	275	
Other	1,563	541
Total scientists	8,270	915
Total scientists and engineers	21,767	1,921

SOURCE: "Study of Scientists and Engineers in DOD Laboratories," conducted by the DOD Laboratory Management Task Force, November 1981-April 1982.

TABLE E-3 Number of Employed Engineers by Field, Federal Agency of Support, and Type of Employer: 1982

			Educational Institutions											
Field and Agency of Support	Total	Business/ Industry	Total	4-year Colleges or Univ.	2-year Colleges	Elem. & Sec. Schools	Hospitals/ Clinics	Nonprofit Organizations	Federal Government	Military/ Commissioned Corps	State Government	Other Government	Other	Not Reported
Engineers	**1,050,872**	**843,952**	**32,148**	**27,406**	**4,070**	**672**	**2,056**	**12,256**	**70,769**	**1,910**	**25,892**	**21,024**	**4,036**	**36,829**
With support[1]	301,452	185,690	12,334	11,003	1,212	119	556	8,084	66,225	1,601	17,106	7,368	1,694	794
AID	1,198	1,131	—	—	—	—	—	—	34	—	—	—	34	—
Dept. of Agriculture	7,400	3,242	693	682	12	—	—	252	2,906	—	120	188	—	—
Dept. of Commerce	3,579	1,888	448	448	—	—	—	187	666	218	86	86	—	—
Dept. of Defense	180,242	129,001	3,310	3,167	143	—	—	4,479	40,985	1,195	271	203	426	371
Dept. of Energy	38,039	26,475	2,634	2,572	52	10	145	2,754	4,536	—	424	178	706	188
Dept. of Education	3,215	906	1,918	1,072	737	109	68	—	170	—	18	135	—	—
Dept. of HHS	4,616	1,990	1,030	988	42	—	342	241	435	154	196	52	143	34
Dept. of HUD	7,106	5,328	—	—	—	—	—	36	213	—	58	1,436	34	—
Dept. of Interior	5,610	1,877	253	253	—	—	—	262	2,434	34	405	312	34	—
Dept. of Justice	676	396	109	109	—	—	—	—	172	—	—	—	—	—
Dept. of Labor	748	278	—	—	—	—	—	—	341	—	94	34	—	—
Dept. of Transport.	35,352	14,641	442	424	18	—	—	729	3,542	—	12,567	3,185	213	34
EPA	20,669	12,592	377	377	—	—	—	299	1,998	34	3,068	2,142	161	—
NASA	37,174	26,694	2,142	2,033	109	—	8	1,265	6,717	34	—	68	152	94
NSF	3,889	1,031	2,460	2,452	8	—	—	330	34	—	—	34	—	—
Nuclear Regul. Comm.	4,603	3,176	177	177	—	—	34	456	584	—	34	—	68	76
Other agency	6,304	2,818	245	245	—	—	68	102	2,483	—	188	291	110	—
Agency unknown[2]	3,528	2,529	199	62	137	—	34	68	183	—	133	365	—	18
No Federal support	652,945	606,187	16,749	14,561	1,810	379	1,145	3,813	2,830	197	6,944	10,557	1,995	2,527
Support not known	35,346	28,538	2,271	1,160	970	140	287	120	316	—	1,162	2,253	261	138
Support not reported	61,130	23,538	794	682	78	34	68	239	1,399	112	680	846	86	33,370

Aeronautical/ Astronautical	**46,007**	**34,919**	**1,706**	**1,672**	**34**	**—**	**—**	**569**	**7,152**	**34**	**34**	**211**	**102**	**1,281**
With support[1]	31,179	22,470	934	934	—	—	—	535	6,961	34	—	102	68	76
AID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	177	68	109	109	—	—	—	—	—	—	—	—	—	—
Dept. of Commerce	10	10	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	22,698	18,306	310	310	—	—	—	337	3,575	34	—	34	68	34
Dept. of Energy	1,188	765	153	153	—	—	—	52	218	—	—	—	—	—
Dept. of Education	34	34	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	34	—	34	34	—	—	—	—	—	—	—	—	—	—
Dept. of HUD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	34	34	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	34	—	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of Transport.	666	114	—	—	—	—	—	34	485	—	—	34	—	—
EPA	18	18	—	—	—	—	—	—	—	—	—	—	—	—
NASA	10,284	6,668	519	519	—	—	—	198	2,756	34	—	68	—	42
NSF	68	68	—	—	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other agency	272	238	—	—	—	—	—	—	34	—	—	—	—	—
Agency unknown[2]	180	180	—	—	—	—	—	—	—	—	—	—	—	—
No Federal support	11,304	10,482	611	611	—	—	—	—	34	—	34	109	34	—
Support not known	1,061	934	127	127	—	—	—	—	—	—	—	—	—	—
Support not reported	2,463	1,034	34	—	34	—	—	34	157	—	—	—	—	1,205

Field and Agency of Support	Total	Business/Industry	Educational Institutions: Total	4-year Colleges or Univ.	2-year Colleges	Elem. & Sec. Schools	Hospitals/Clinics	Nonprofit Organizations	Federal Government	Military/Commissioned Corps	State Government	Other Government	Other	Not Reported
Chemical	**61,277**	**54,945**	**1,905**	**1,671**	**234**	**—**	**—**	**905**	**1,465**	**52**	**295**	**195**	**86**	**1,430**
With support[1]	6,775	3,783	682	682	—	—	—	515	1,415	52	253	—	34	42
AID	143	109	—	—	—	—	—	—	—	—	—	—	34	—
Dept. of Agriculture	143	109	34	34	—	—	—	—	—	—	—	—	—	—
Dept. of Commerce	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	2,394	1,215	92	92	—	—	—	211	825	52	—	—	—	—
Dept. of Energy	3,617	2,458	412	412	—	—	—	364	240	—	109	—	—	34
Dept. of Education	260	8	218	218	—	—	—	—	34	—	—	—	—	—
Dept. of HHS	34	—	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of HUD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	313	151	—	—	—	—	—	—	128	—	34	—	—	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Transport.	127	109	18	18	—	—	—	—	—	—	—	—	—	—
EPA	604	214	—	—	—	—	—	76	203	—	110	—	—	—
NASA	448	312	109	109	—	—	—	27	—	—	—	—	—	—
NSF	244	143	102	102	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	427	218	—	—	—	—	—	201	—	—	—	—	—	8
Other agency	8	8	—	—	—	—	—	—	—	—	—	—	—	—
Agency unknown[2]	52	34	—	—	—	—	—	—	18	—	—	—	—	—
No Federal support	51,026	49,193	1,114	880	234	—	—	390	42	—	42	68	34	143
Support not known	1,193	1,157	—	—	—	—	—	—	—	—	—	18	18	—
Support not reported	2,283	812	109	109	—	—	—	—	8	—	—	109	—	1,245

Civil	**145,955**	**90,456**	**3,792**	**3,397**	**265**	**129**	**102**	**841**	**13,268**	**353**	**17,763**	**13,501**	**768**	**5,112**
With support[1]	52,575	20,742	916	844	62	10	—	478	12,482	319	12,300	4,875	364	98
AID	263	229	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of Agriculture	3,053	1,150	34	34	—	—	—	—	1,632	—	68	170	—	—
Dept. of Commerce	636	252	—	—	—	—	—	—	47	218	68	52	—	—
Dept. of Defense	12,594	5,978	171	171	—	—	—	76	6,200	68	68	34	—	—
Dept. of Energy	2,791	1,969	44	34	—	10	—	153	489	—	34	—	34	68
Dept. of Education	398	52	143	109	34	—	—	—	68	—	—	135	—	—
Dept. of HHS	1,103	822	—	—	—	—	—	—	52	34	34	52	109	—
Dept. of HUD	4,414	3,051	—	—	—	—	—	18	135	—	40	1,170	—	—
Dept. of Interior	2,274	581	151	151	—	—	—	—	1,287	—	154	102	—	—
Dept. of Justice	171	62	109	109	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	136	34	—	—	—	—	—	—	34	—	34	34	—	—
Dept. of Transport.	23,896	8,179	247	229	18	—	—	223	1,411	—	11,031	2,626	179	—
EPA	8,224	5,968	34	34	—	—	—	—	349	—	749	997	127	—
NASA	709	599	—	—	—	—	—	—	110	—	—	—	—	—
NSF	581	120	427	427	—	—	—	—	—	—	—	34	—	—
Nuclear Regul. Comm.	410	180	109	109	—	—	—	58	28	—	—	—	—	34
Other agency	1,525	445	—	—	—	—	—	—	723	—	102	213	42	—
Agency unknown[2]	920	519	19	8	10	—	—	—	42	—	94	227	—	18
No Federal support	79,597	63,998	2,538	2,343	86	109	102	296	564	34	4,259	7,051	318	438
Support not known	5,869	3,476	229	102	117	10	—	34	76	—	809	1,178	68	—
Support not reported	7,914	2,239	109	109	—	—	—	34	146	—	395	396	18	4,577

Field and Agency of Support	Total	Business/ Industry	Educational Institutions: Total	4-year Colleges or Univ.	2-year Colleges	Elem. & Sec. Schools	Hospitals/ Clinics	Nonprofit Organizations	Federal Government	Military/ Commissioned Corps	State Government	Other Government	Other	Not Reported
Electrical/Electronic	**245,781**	**200,359**	**7,511**	**6,492**	**975**	**44**	**273**	**4,018**	**20,990**	**503**	**1,000**	**1,821**	**814**	**8,493**
With support[1]	77,362	50,991	2,577	2,373	204	—	117	2,720	19,234	482	334	326	313	268
AID	170	170	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	891	628	—	—	—	—	—	143	120	—	—	—	—	—
Dept. of Commerce	1,237	569	109	109	—	—	—	109	451	—	—	—	—	—
Dept. of Defense	60,416	42,748	1,040	1,007	34	—	—	1,880	13,872	482	—	68	177	148
Dept. of Energy	7,008	4,417	264	246	18	—	—	576	1,436	—	44	102	136	34
Dept. of Education	306	128	144	8	136	—	—	—	34	—	—	—	—	—
Dept. of HHS	1,129	215	432	424	8	—	109	195	110	—	—	—	34	34
Dept. of HUD	538	452	—	—	—	—	—	18	34	—	—	34	—	—
Dept. of Interior	441	226	—	—	—	—	—	119	96	—	—	—	—	—
Dept. of Justice	289	188	—	—	—	—	—	—	102	—	—	—	—	—
Dept. of Labor	172	136	—	—	—	—	—	—	37	—	—	—	—	—
Dept. of Transport.	3,523	1,941	109	109	—	—	—	177	989	—	203	104	—	—
EPA	1,064	588	68	68	—	—	—	143	136	—	18	112	—	—
NASA	9,942	6,107	898	898	—	—	8	720	2,122	—	—	—	34	52
NSF	1,122	244	649	641	8	—	—	229	—	—	—	—	—	—
Nuclear Regul. Comm.	634	446	—	—	—	—	—	—	120	—	34	—	34	—
Other agency	1,455	639	—	—	—	—	—	68	646	—	68	34	—	—
Agency unknown[2]	911	772	20	20	—	—	—	34	78	—	—	8	—	—
No Federal support	145,523	136,572	3,970	3,425	545	—	122	1,212	1,118	10	638	1,045	431	404
Support not known	7,851	6,723	695	425	226	44	34	52	71	—	18	188	70	—
Support not reported	15,046	6,072	269	269	—	—	—	34	567	10	10	262	—	7,821

Industrial	**67,937**	**60,654**	**1,171**	**1,026**	**145**	—	**435**	**397**	**2,437**	**52**	**162**	**504**	**71**	**2,055**
With support[1]	11,071	8,047	399	273	127	—	153	68	2,215	42	76	34	3	34
AID	42	42	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	34	—	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of Commerce	127	127	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	8,979	6,721	285	177	109	—	—	34	1,860	42	—	34	3	—
Dept. of Energy	827	572	44	44	—	—	109	34	68	—	—	—	—	—
Dept. of Education	34	—	34	34	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	333	86	18	18	—	—	153	—	—	—	76	—	—	—
Dept. of HUD	78	78	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	21	—	—	—	—	—	—	—	21	—	—	—	—	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Transport.	433	399	—	—	—	—	—	—	34	—	—	—	—	—
EPA	143	143	—	—	—	—	—	—	—	—	—	—	—	—
NASA	1,381	1,381	—	—	—	—	—	—	—	—	—	—	—	—
NSF	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	244	210	—	—	—	—	—	—	—	—	—	—	—	34
Other agency	110	42	—	—	—	—	—	—	68	—	—	—	—	—
Agency unknown[2]	83	55	18	—	18	—	—	—	10	—	—	—	—	—
No Federal support	50,035	48,039	758	750	8	—	206	319	112	10	52	328	34	178
Support not known	2,891	2,636	3	3	—	—	8	—	34	—	34	143	34	—
Support not reported	3,939	1,932	10	—	10	—	68	10	76	—	—	—	—	1,843

Field and Agency of Support	Total	Business/ Industry	Educational Institutions: Total	Educational Institutions: 4-year Colleges or Univ.	Educational Institutions: 2-year Colleges	Educational Institutions: Elem. & Sec. Schools	Hospitals/ Clinics	Nonprofit Organizations	Federal Government	Military/ Commissioned Corps	State Government	Other Government	Other	Not Reported
Materials	**22,886**	**19,181**	**1,670**	**1,652**	**18**	**—**	**—**	**214**	**1,220**	**—**	**71**	**34**	**127**	**369**
With support[1]	6,816	4,129	1,161	1,161	—	—	—	94	1,200	—	37	34	127	34
AID	18	18	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Commerce	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	4,454	3,178	480	480	—	—	—	42	719	—	—	—	—	34
Dept. of Energy	1,852	873	464	464	—	—	—	60	312	—	34	—	109	—
Dept. of Education	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HUD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	120	52	—	—	—	—	—	—	68	—	—	—	—	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Transport.	60	52	—	—	—	—	—	8	—	—	—	—	—	—
EPA	68	68	—	—	—	—	—	—	—	—	—	—	—	—
NASA	1,180	1,045	34	34	—	—	—	8	93	—	—	—	—	—
NSF	537	—	503	503	—	—	—	34	—	—	—	—	—	—
Nuclear Regul. Comm.	136	68	—	—	—	—	—	—	68	—	—	—	—	—
Other agency	243	34	142	142	—	—	—	—	67	—	—	—	—	—
Agency unknown[2]	63	27	—	—	—	—	—	—	—	—	3	34	—	—
No Federal support	14,474	14,025	382	382	—	—	—	68	—	—	—	—	—	—
Support not known	674	580	18	—	18	—	—	34	—	—	34	—	—	8
Support not reported	921	447	109	109	—	—	—	18	20	—	—	—	—	326

Mechanical	**206,943**	**179,611**	**7,136**	**5,210**	**1,671**	**255**	**409**	**1,906**	**9,587**	**170**	**652**	**1,152**	**424**	**5,896**
With support[1]	44,335	30,777	2,354	1,708	537	109	86	1,379	8,854	68	197	348	144	130
AID	177	177	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	457	244	—	—	—	—	—	109	86	—	18	—	—	—
Dept. of Commerce	527	380	34	34	—	—	—	34	61	—	18	—	—	—
Dept. of Defense	29,194	21,283	534	534	—	—	—	688	6,424	68	52	34	34	78
Dept. of Energy	9,054	6,756	502	469	34	—	18	954	559	—	111	34	68	52
Dept. of Education	1,275	315	908	405	394	109	—	—	34	—	18	—	—	—
Dept. of HHS	966	448	352	319	34	—	—	12	136	—	18	—	—	—
Dept. of HUD	520	492	—	—	—	—	—	—	—	—	—	28	—	—
Dept. of Interior	518	170	—	—	—	—	—	109	188	—	52	—	—	—
Dept. of Justice	34	34	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	18	—	—	—	—	—	—	—	—	—	18	—	—	—
Dept. of Transport.	1,981	1,640	68	68	—	—	—	12	151	—	—	110	—	—
EPA	1,328	988	34	34	—	—	—	12	122	—	34	138	—	—
NASA	7,134	5,587	387	278	109	—	—	189	929	—	—	—	42	—
NSF	624	132	492	492	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	988	868	—	—	—	—	—	86	34	—	—	—	—	—
Other agency	833	455	8	8	—	—	34	34	302	—	—	—	—	—
Agency unknown[2]	415	313	34	34	—	—	34	—	34	—	—	—	—	—
No Federal support	144,550	137,760	4,208	3,214	883	112	256	527	354	—	370	352	218	505
Support not known	7,716	6,445	506	221	252	34	68	—	102	—	52	419	62	62
Support not reported	10,341	4,629	68	68	—	—	—	—	276	102	34	34	—	5,199

Field and Agency of Support	Total	Business/ Industry	Educational Institutions: Total	Educational Institutions: 4-year Colleges or Univ.	Educational Institutions: 2-year Colleges	Educational Institutions: Elem. & Sec. Schools	Hospitals/ Clinics	Nonprofit Organizations	Federal Government	Military/ Commissioned Corps	State Government	Other Government	Other	Not Reported
Mining	**7,334**	**6,249**	**311**	**303**	**8**	**—**	**—**	**109**	**307**	**—**	**159**	**52**	**34**	**114**
With Support[1]	833	321	52	52	—	—	—	—	307	—	86	34	34	—
AID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	34	—	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of Commerce	34	—	—	—	—	—	—	—	—	—	—	34	—	—
Dept. of Defense	142	68	34	34	—	—	—	—	41	—	—	—	—	—
Dept. of Energy	123	123	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Education	3	3	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	34	34	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HUD	86	52	—	—	—	—	—	—	—	—	—	—	34	—
Dept of Interior	219	63	—	—	—	—	—	—	122	—	—	—	34	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	76	—	—	—	—	—	—	—	76	—	—	—	—	—
Dept. of Transport.	185	99	—	—	—	—	—	—	—	—	86	—	—	—
EPA	52	18	—	—	—	—	—	—	—	—	—	—	34	—
NASA	34	34	—	—	—	—	—	—	—	—	—	—	—	—
NSF	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other agency	52	—	18	18	—	—	—	—	34	—	—	—	—	—
Agency unknown[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No Federal support	6,124	5,637	260	252	8	—	—	109	—	—	54	18	—	46
Support not known	146	128	—	—	—	—	—	—	—	—	18	—	—	—
Support not reported	231	163	—	—	—	—	—	—	—	—	—	—	—	68

Nuclear	**9,657**	**6,771**	**203**	**203**	—	—	**34**	**207**	**1,725**	—	**18**	**109**	**177**	**414**
With support[1]	4,614	2,440	170	170	—	—	34	130	1,589	—	—	109	143	—
AID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Commerce	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	1,569	821	—	—	—	—	—	—	748	—	—	—	—	—
Dept. of Energy	2,929	1,998	136	136	—	—	—	130	523	—	—	—	143	—
Dept. of Education	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HUD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	109	—	—	—	—	—	—	—	—	—	—	109	—	—
Dept. of Justice	36	—	—	—	—	—	—	—	36	—	—	—	—	—
Dept. of Labor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Transport.	92	—	—	—	—	—	—	—	92	—	—	—	—	—
EPA	161	127	—	—	—	—	—	—	34	—	—	—	—	—
NASA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NSF	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	1,197	787	68	68	—	—	34	8	300	—	—	—	—	—
Other agency	68	34	—	—	—	—	—	—	34	—	—	—	—	—
Agency unknown[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No Federal support	4,345	4,081	34	34	—	—	—	77	102	—	18	—	34	—
Support not known	86	86	—	—	—	—	—	—	—	—	—	—	—	—
Support not reported	612	164	—	—	—	—	—	—	34	—	—	—	—	414

			Educational Institutions											
Field and Agency of Support	Total	Business/Industry	Total	4-year Colleges or Univ.	2-year Colleges	Elem. & Sec. Schools	Hospitals/Clinics	Nonprofit Organizations	Federal Government	Military/Commissioned Corps	State Government	Other Government	Other	Not Reported
Petroleum	**14,165**	**12,252**	**66**	**66**	**—**	**—**	**—**	**109**	**379**	**—**	**211**	**—**	**143**	**1,006**
With support[1]	641	120	34	34	—	—	—	109	379	—	—	—	—	—
AID	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Commerce	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Defense	179	—	—	—	—	—	—	109	70	—	—	—	—	—
Dept. of Energy	314	120	34	34	—	—	—	—	160	—	—	—	—	—
Dept. of Education	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HHS	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of HUD	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Interior	128	—	—	—	—	—	—	—	128	—	—	—	—	—
Dept. of Justice	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Labor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Transport.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EPA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NASA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NSF	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nuclear Regul. Comm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other agency	54	—	—	—	—	—	—	—	54	—	—	—	—	—
Agency unknown[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No Federal support	12,157	11,653	24	24	—	—	—	—	—	—	211	—	143	127
Support not known	161	153	8	8	—	—	—	—	—	—	—	—	—	—
Support not reported	1,205	326	—	—	—	—	—	—	—	—	—	—	—	879

Other	**222,930**	**178,557**	**6,677**	**5,714**	**719**	**244**	**803**	**2,981**	**12,240**	**746**	**5,528**	**3,446**	**1,292**	**10,660**
With support[1]	65,250	41,872	3,056	2,774	282	—	166	2,056	11,588	603	3,825	1,507	465	112
AID	386	386	—	—	—	—	—	—	—	—	—	—	—	—
Dept. of Agriculture	2,612	1,043	517	505	12	—	—	—	1,000	—	34	18	—	—
Dept. of Commerce	1,007	551	305	305	—	—	—	44	107	—	—	—	—	—
Dept. of Defense	37,622	28,684	362	362	—	—	—	1,101	6,651	449	152	—	145	78
Dept. of Energy	8,337	6,424	581	581	—	—	18	430	532	—	92	42	218	—
Dept. of Education	906	366	471	299	173	—	68	—	—	—	—	—	—	—
Dept. of HHS	983	385	193	193	—	—	80	34	104	120	68	—	—	—
Dept. of HUD	1,470	1,204	—	—	—	—	—	—	44	—	18	203	—	—
Dept. of Interior	1,433	602	102	102	—	—	—	34	395	34	165	102	—	—
Dept. of Justice	145	112	—	—	—	—	—	—	34	—	—	—	—	—
Dept. of Labor	312	109	—	—	—	—	—	—	161	—	42	—	—	—
Dept. of Transport.	4,389	2,109	—	—	—	—	—	275	380	—	1,247	311	34	34
EPA	9,007	4,460	241	241	—	—	—	68	1,154	34	2,156	894	—	—
NASA	6,062	4,961	195	195	—	—	—	124	706	—	—	—	76	—
NSF	713	324	287	287	—	—	—	68	34	—	—	—	—	—
Nuclear Regul. Comm.	568	399	—	—	—	—	—	102	34	—	—	—	34	—
Other agency	1,684	923	77	77	—	—	34	—	520	—	18	44	68	—
Agency unknown[2]	904	629	109	—	109	—	—	34	—	—	36	96	—	—
No Federal support	133,809	124,746	2,850	2,646	46	158	460	817	503	143	1,267	1,586	750	687
Support not known	7,696	6,220	685	275	358	52	177	—	34	—	197	308	8	68
Support not reported	16,175	5,720	86	18	34	34	—	109	115	—	240	44	68	9,794

NOTE: Detail may not add to total due to rounding. HHS = Health and Human Services; HUD = Housing and Urban Development; EPA = Environmental Protection Agency; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation.

[1] Sum of support agencies may exceed total with support due to multiple responses.

[2] Includes agency not reported.

SOURCE: Adapted from *The 1982 Postcensal Survey of Scientists and Engineers*. Surveys of Science Resources Series. NSF 84-330 (Washington, D.C.: National Science Foundation, 1984, Table B-14).

TABLE E-4 Federal Obligations for Basic Research in Engineering Performed at Universities and Colleges: Fiscal Years 1982, 1983, and 1984 (thousands of dollars)

		Estimates	
Field of Science	Actual, 1982	1983	1984
Engineering, total	259,013	277,886	333,393
Aeronautical	25,203	25,747	28,954
Aeronautical	3,532	7,405	10,079
Chemical	16,802	18,582	22,841
Civil	18,966	21,260	26,669
Electrical	61,064	59,856	75,793
Mechanical	32,106	33,831	40,171
Metallurgy & materials	69,648	74,320	87,372
Engineering, NEC	31,692	36,885	41,514

SOURCE: Adapted from *Federal Funds for Research and Development: Fiscal Years 1982 1983, and 1984*. Vol. 32. Surveys of Science Resources Series. NSF 83.319 (Washington, D. C.: National Science Foundation, Table C-85).

TABLE E-5 Federal Obligations for Basic Research Performed at Universities and Colleges in Engineering, by Agency and Detailed Field of Science: Fiscal Year 1982 (thousands of dollars)

	Engineering								
Agency and Subdivision	Total	Aero-nautical	Astro-nautical	Chemical	Civil	Elec-trical	Mechan-ical	Metal-lurgy and Materials	Engi-neering NEC
Total, all agencies	259,013	25,203	3,532	16,802	18,966	61,064	32,106	69,648	31,692
Departments									
Department of Agriculture, total	3,302	—	—	107	46	11	28	—	3,110
Agricultural Research Service	841	—	—	107	46	11	28	—	649
Cooperative State Research Service	2,461	—	—	—	—	—	—	—	2,461
Department of Defense, total	97,418	13,278	2,099	1,469	966	34,740	14,278	30,528	60
Department of the Army	20,577	3,392	—	64	100	9,571	2,120	5,270	60
Department of the Navy	33,330	376	—	1,387	—	13,584	8,266	9,717	—
Department of the Air Force	34,654	9,510	2,099	—	866	9,029	3,892	9,258	—
Defense agencies	8,857	—	—	18	—	2,556	—	6,283	—
Department of Energy	15,773	—	—	—	—	—	2,291	11,900	1,582
Dept. of Health & Human Services, total	17,897	—	—	—	—	—	—	—	17,897
National Institutes of Health	17,897	—	—	—	—	—	—	—	17,897
Other agencies									
National Aeronautics & Space Admin.	26,668	11,638	1,264	348	320	2,466	2,496	5,853	2,283
National Science Foundation	97,955	287	169	14,878	17,634	23,847	13,013	21,367	6,760

NOTE: The basic research obligations of the six agencies included in this table represent approximately 99 percent of total federal basic research obligations to universities and colleges in FY 1982.

SOURCE: *Federal Funds for Research and Development: Fiscal Years 1982, 1983, and 1984*. Vol. 32. Surveys of Science Resources Series. NSF 83-319 (Washington, D.C.: National Science Foundation, Table C-89).

TABLE E-6 Federal Obligations for Applied Research in Engineering Performed at Universities and Colleges: Fiscal Years 1982, 183, and 1984 (thousands of dollars)

		Estimates	
Field of Science	Actual, 1982	1983	1984
Engineering, total	102,495	111,382	113,328
Aeronautical	13,292	13,594	14,062
Astronautical	6,050	8,444	6,173
Chemical	2,617	2,915	3,011
Civil	8,172	7,173	6,808
Electrical	27,547	28,741	32,582
Mechanical	8,380	9,074	8,605
Metallurgy & materials	5,694	6,276	7,200
Engineering, NEC	30,743	35,165	34,887

SOURCE: Adapted for *Federal Funds for Research and Development: Fiscal Years 1982, 1983, and 1984*. Vol. 32. Surveys of Science Resources Series. NSF 83-319 (Washington, D. C.: National Science Foundation, Table C-91).

TABLE E-7 Federal Obligations for Applied Research Performed at Universities and Colleges in Engineering, by Agency and Detailed Field of Science: Fiscal Year 1982 (thousands of dollars)

	Engineering								
Agency and Subdivision	Total	Aeronautical	Astronautical	Chemical	Civil	Electrical	Mechanical	Metallurgy and Materials	Engineering NEC
Total, all agencies	102,495	13,292	6,050	2,617	8,172	27,547	8,380	5,694	30,743
Departments									
Department of Agriculture, total	5,760	—	—	130	108	14	56	—	5,452
Agricultural Research Service	1,568	—	—	130	108	14	56	—	1,260
Cooperative State Research Service	4,192	—	—	—	—	—	—	—	4,192
Department of Defense, total	48,913	9,499	5,409	465	1,783	20,693	4,421	3,508	3,135
Department of the Army	6,675	342	100	106	1,327	2,595	895	382	928
Department of the Navy	3,860	122	—	105	95	602	2,608	198	130
Department of the Air Force	31,833	9,018	4,478	254	226	14,749	918	1,394	796
Defense agencies	6,545	17	831	—	135	2,747	—	1,534	1,281
Department of Energy	12,110	—	234	173	1,548	1,559	23	10	8,563
Dept. of Health & Human Services, total	10,431	—	—	—	—	—	—	—	10,431
National Institutes of Health	10,431	—	—	—	—	—	—	—	10,431
Other agencies									
National Aeronautics & Space Admin.	11,846	3,781	406	45	—	1,960	2,687	467	2,500
National Science Foundation	13,435	12	1	1,804	4,733	3,321	1,193	1,709	662

NOTE: The applied research obligations of the six agencies included in this table represent approximately 84 percent of total federal applied research obligations to universities and colleges in FY 1982.

SOURCE: *Federal Funds for Research and Development: Fiscal Years 1982, 1983, and 1984.* Vol. 32. Surveys of Science Resources Series. NSF 83-319 (Washington, D.C.: National Science Foundation, Table C-95).

TABLE E-8 Graduate Predoctoral Fellowships in Engineering Funded by Federal Agencies

Agency	Approximate Number of Fellows	Stipend	Institutional Allowance	Tuition Paid	Approximate Annual Support (in thousands)
Dept. of Defense					
Air Force	90	$13,000-14,00	$2,00	yes	$1,800
Army	35	13,00-14,00	2,000	yes	700
Navy	66	13,00-14,000	2,000	yes	1,320
Dept. of Energy	64	12,00	6,000	no	1,675
NASA	36	10,000 (+3,000[1])	2,00	no	540
NSF	112	8,100	4,900	no	1,456
Total	417				$7,491

NOTE: Numbers of fellowship and stipend levels are for early 1984.

1 Allowance for Fellow to conduct research at NASA Laboratory.

TABLE E-9 Estimated Annual Direct Support of Engineering Education by Agencies of the Federal Government

Category	Estimated Annual Expenditure (thousands of dollars)
Research and development contracts and grants	761,000
Undergraduate student aid	129,000
Graduate fellowship[1]	7,500
Research equipment[1]	15,000
Total	905,000

[1] In addition to amounts provided through research contracts and grants.