PREPARING FOR SCIENCE AND ENGINEERING CAREERS

FIELD-LEVEL PROFILES

INTRODUCTION AND HIGHLIGHTS

This Staff Paper is an addendum to Demographic Trends and the Scientific and Engineering Work Force, an OTA Technical Memorandum published in December 1985. The paper was produced in response to a request by the Committee on Science and Technology of the House of Representatives, to examine differences in the supply and demand of personnel across individual fields of science and engineering, and the sensitivity of these fields to demographic trends.

The document consists of a dozen profiles presented in five broad field categories: the physical sciences (physics and astronomy, chemistry, earth and environmental sciences); mathematical and computer sciences; the life sciences (biological, health/medical, agricultural); social and behavioral sciences (psychology, economics); and engineering (chemical, electrical). All profiles include trend data on enrollments, degrees conferred, and employment by sector and primary work activity. Detailed information is also given on preparation for careers in science and engineering of three groups of people: women, minorities, and foreign nationals. The time period covered by most of the descriptive statistics is 1960-86.

The paper illustrates differences in the education and entry-level employment of degreed science and engineering talent, especially characteristics that are obscured by aggregated data analysis. A brief narrative introduces each broad field section and a series of graphs and charts accompanies each profile. [n addition, a note on data precedes the profiles; this note provides an overview of data sources and explains important idiosyncrasies of their reporting.

Each field profile has been written as a self-contained section. **As** the individual field or discipline is a smaller, more uniform population than the science and engineering work force as a whole, each field tends to have a characteristic pattern of education and employment. Analysis at the level of the field can improve understanding of how different market forces, demographic factors, and public policies interact to affect the supply of and demand for scientists and engineers. The following are highlights of a disaggregate analysis. Such analysis augments generalizations about the science and engineering work force as a whole.

1. The smaller and more specialized the scientific field being studied, the less predictable are changes in the factors that affect demand, such as scientific and technological **advances,** shifts in Federal funding priorities, and industrial research and development **(R&D)** spending, Small changes in the total supply of scientists and engineers can mask significant adjustment within and among fields. The total number of Ph.D.s awarded in science and engineering rose by 7 percent between 1980 and 1985. During this period, physics Ph.D. awards rose 10 percent and mathematics Ph.D.s declined almost as much. Both were overshadowed, however, by an increase in computer science Ph.D.s of 35 percent. The relationship between fields, especially mathematics and computer science, is critical for interpreting these degree trends.

2. Demographic trends play very little, if any, role in the supply of scientists or engineers in individual fields or in one field relative to another. Some demand factors affect all science and engineering, such as the general health of the U.S. industrial economy and the level of Federal R&D funding. Although the national economy may be healthy and the overall demand for scientists and engineers strong, a downturn in the oil industry will quench the demand for petroleum engineers. Similarly, a shift in emphasis within Federal R&D funding, even though overall R&D funding remains stable, can significantly change the demand in particular fields while not changing the total demand for scientists.

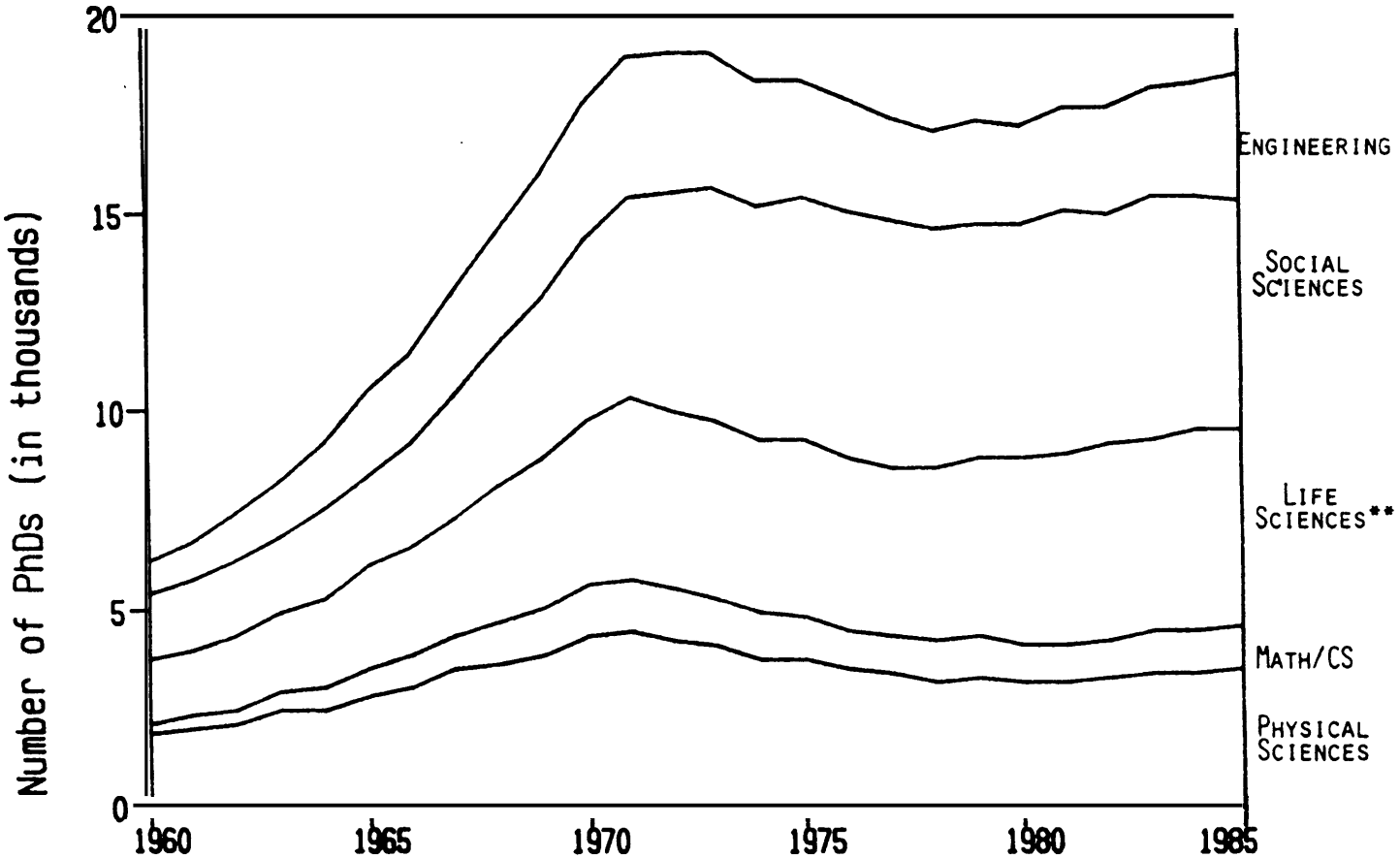
3. Graduate enrollments and degree awards are highly responsive to small shifts in Federal education and research support. In academic sciences such as mathematics, the life sciences, and astronomy, Federal Government support dominates. In industry-oriented fields, students respond quickly to changes in the job market. For example, unprecedented growth in the U.S. computer and semiconductor industries in the late 1970s generated a large demand for electrical engineers and computer specialists, which was answered quickly with an equally unprecedented boom in undergraduate electrical engineering enrollments.

4. Breadth of employment brings stability to a field. Chemical and mechanical engineers work in many different industries and can move among them. Petroleum engineers, on the other hand, depend almost exclusively on the petroleum industry for jobs. Diversity of employment may also tend to encourage broader education and a more versatile and mobile work force. Prospects for employment, not demographics, may be the key factor in maintaining the supply of talent in afield.

5. Labor markets adjust to supply-demand gaps. The Federal role in alleviating potential shortages of technical personnel appears limited to assistance for education and retraining. Shortages and surpluses are most likely to arise at the level of the specialty or skill rather than the field, and are more likely at the level of the field than for science and engineering as a whole. While petroleum geologists are currently over-supplied, hydrologists are in demand to address rising concern over groundwater supplies and quality.

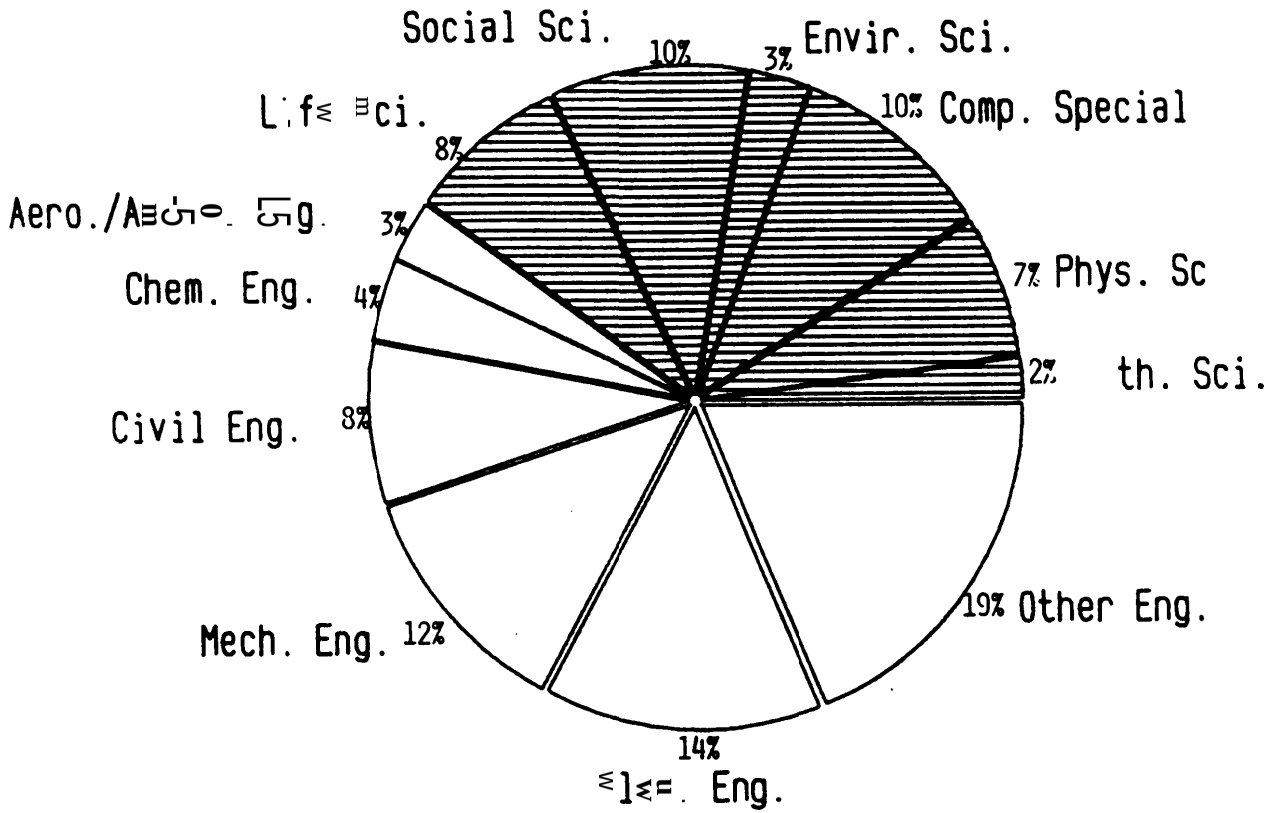
6. The labor market adjusts to supply-demand gaps in two ways: individuals already in the work force change jobs and, after a lag, the number of degrees awarded in that field changes. Students are likely to shift specialties within afield before they shift fields, and more likely to shift fields than opt out of science or engineering altogether. Students may prolong their education until a poor job market improves, or hasten entry meet changing skill requirements and job opportunities; few scientists (especially

Number of S/E* PhDs by Broad Field, 1960-1985



*SCIENCE/ENGINEERING **EXCEPT HEALTH SOURCE: NATIONAL RESEARCH COUNCIL

U.S. Scientists/Engineers* by Field, 1986

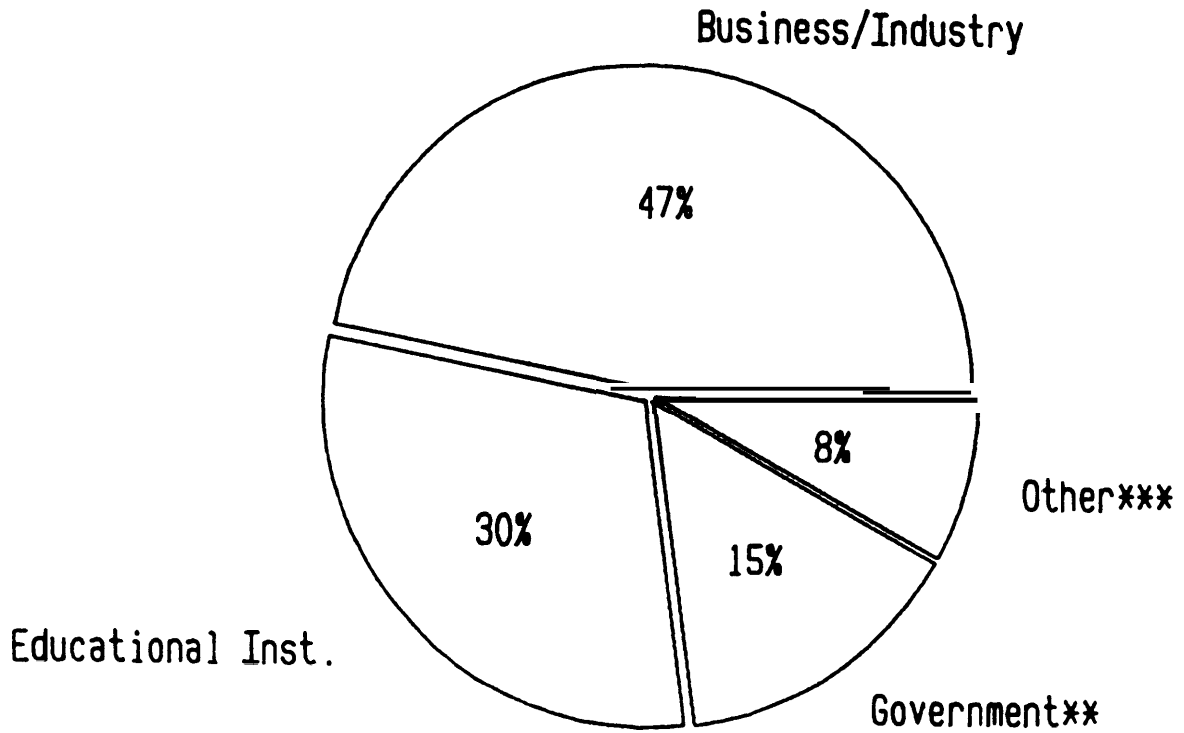


SCIENTISTS
ENGINEERS

* 1 DEGREE

SOURCE: NATIONAL SCIENCE FOUNDATION

Sc by Sector of Employment, 1

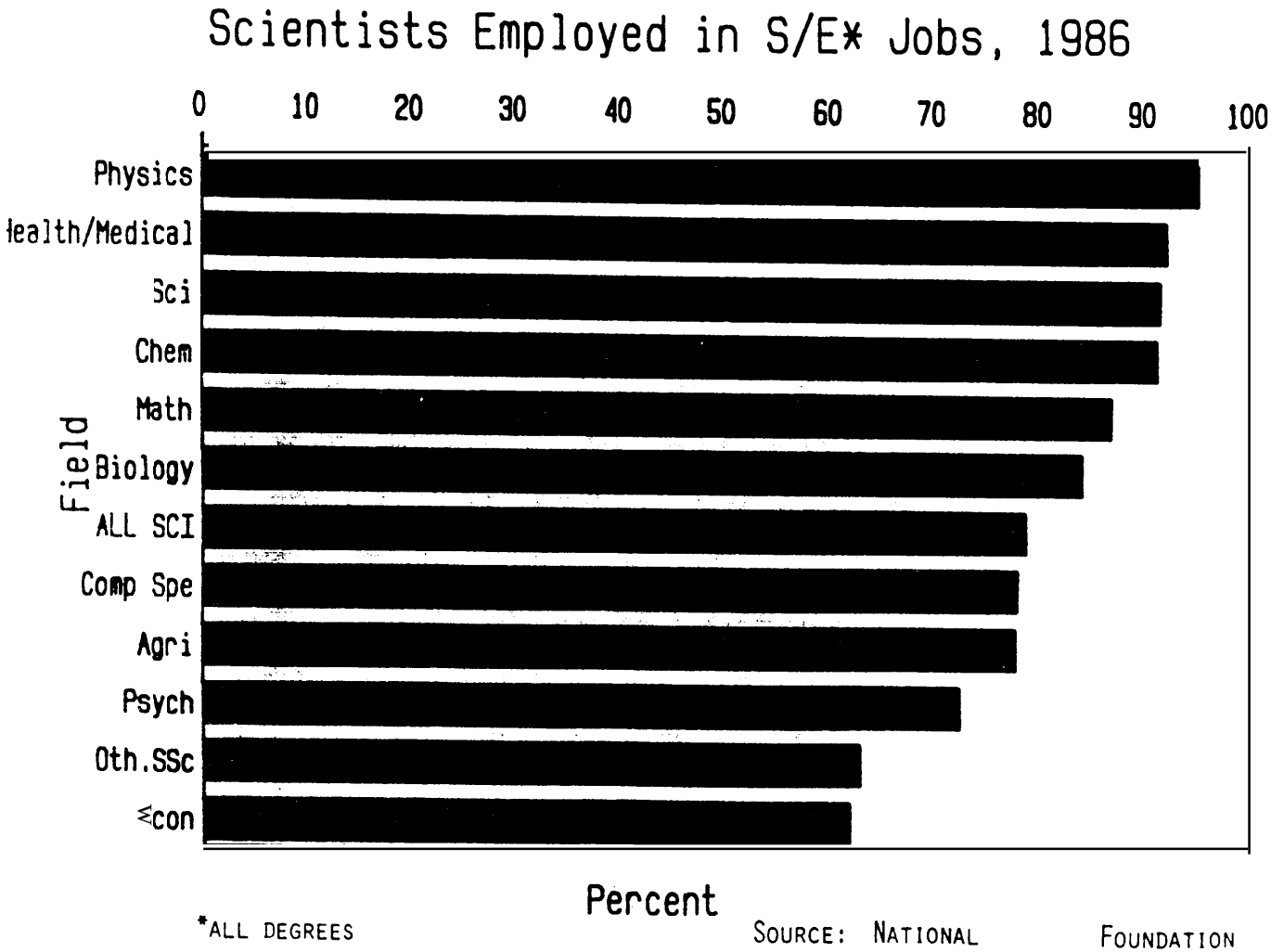


*ALL DEGREES

*INCLUDES FEDERAL, STATE/LOCAL, AND OTHER GOVERNMENT

** INCLUDES NONPROFIT INSTITUTIONS, MILITARY AND ALL AND NO REPORT

SOURCE: NATIONAL SCIENCE FOUNDATION



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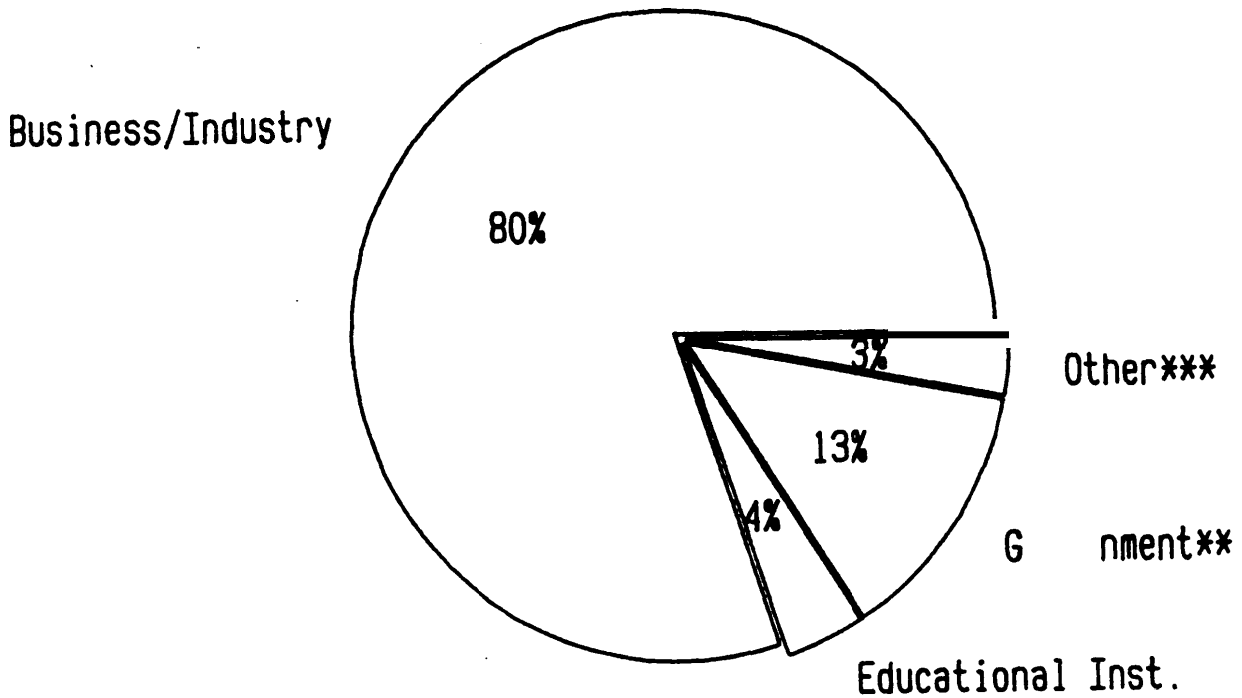
SOURCE: NATIONAL FOUNDATION

Engineers* by Sector of ployment, 1986



*ALL DEGREES

**INCLUDES FEDERAL, STATE/LOCAL, AND OTHER GOVERNMENT

***INCLUDES NONPROFIT INSTITUTIONS, MILIT AND ALL OTHER, AND

SOURCE: NATIONAL SCIENCE FOUNDATION REPORT

mathematicians and physicists) emigrate to other fields. This mobility stems both from a recognition of individual versatility (in pursuing research problems and funding) and the continuing oversupply of Ph.D.s relative to opportunities for research positions in one's original field.

7. Recent engineering graduates seem well able to shift to meet new challenges; scientists are flexible to a lesser degree because of their longer and more specialized professional training. Engineering students can be more responsive than science students to current market conditions because of the relatively short time lag between selecting an engineering specialty, sometimes as late as the junior year of college, and obtaining the professional credential of a bachelor's degree. The total number of B.S.* degrees awarded in engineering doubled between 1975 and 1985. Computer and electrical engineering exceeded this rate and added over 15,000 to the work force during this period.

8. The scope of fields and the boundaries between them a.re constantly changing. Whether a researcher in laser optics should be counted as a physicist or an engineer is a matter of judgment rather than hard-and-fast definition. New interdisciplinary fields emerge from cross-fertilization between subfields or as spinoffs from a fruitful line of research in an established discipline. Categories tend to lag the reality of emerging disciplines. This makes it especially difficult to track disciplines in their formative years. Reliable data on computer scientists and materials scientists, for instance, are just beginning to be available.

9. The level of women's participation in science and engineering varies significantly by field. Women have made gradual gains over the past 15 years in science and engineering, though increases have slowed in recent years. In 1985, their share of science and engineering Ph.D.s declined for the first time, although the decrease was all

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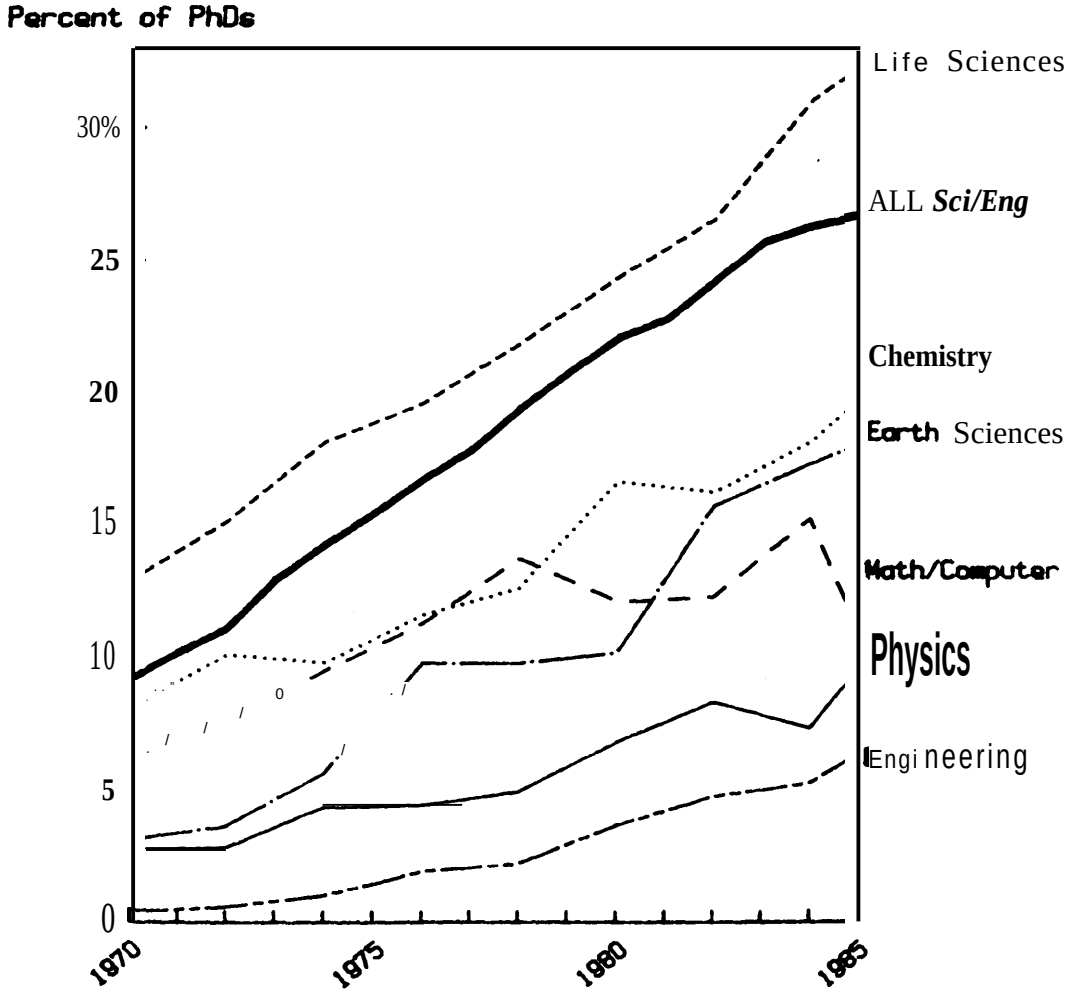
* "B.S." is used throughout the Paper as a shorthand for all baccalaureate degrees by any designation.

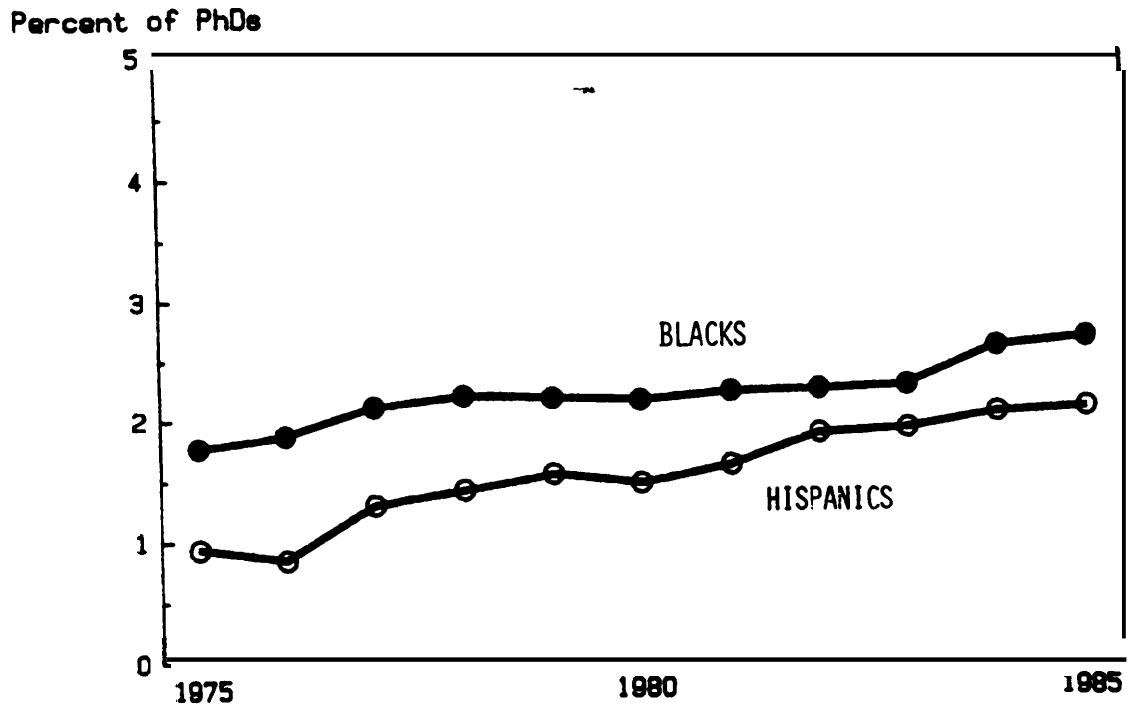
Women as a Proportion of PhDs
Al 1 S/E* Fields. 1970-1985



*SCIENCE/ENGINEERING

SOURCE: 'NATIONAL RESEARCH COUNCIL

BLACKS AND HISPANICS
AS PROPORT ON* OF ALL SCIENCE/ENG
1975-1985



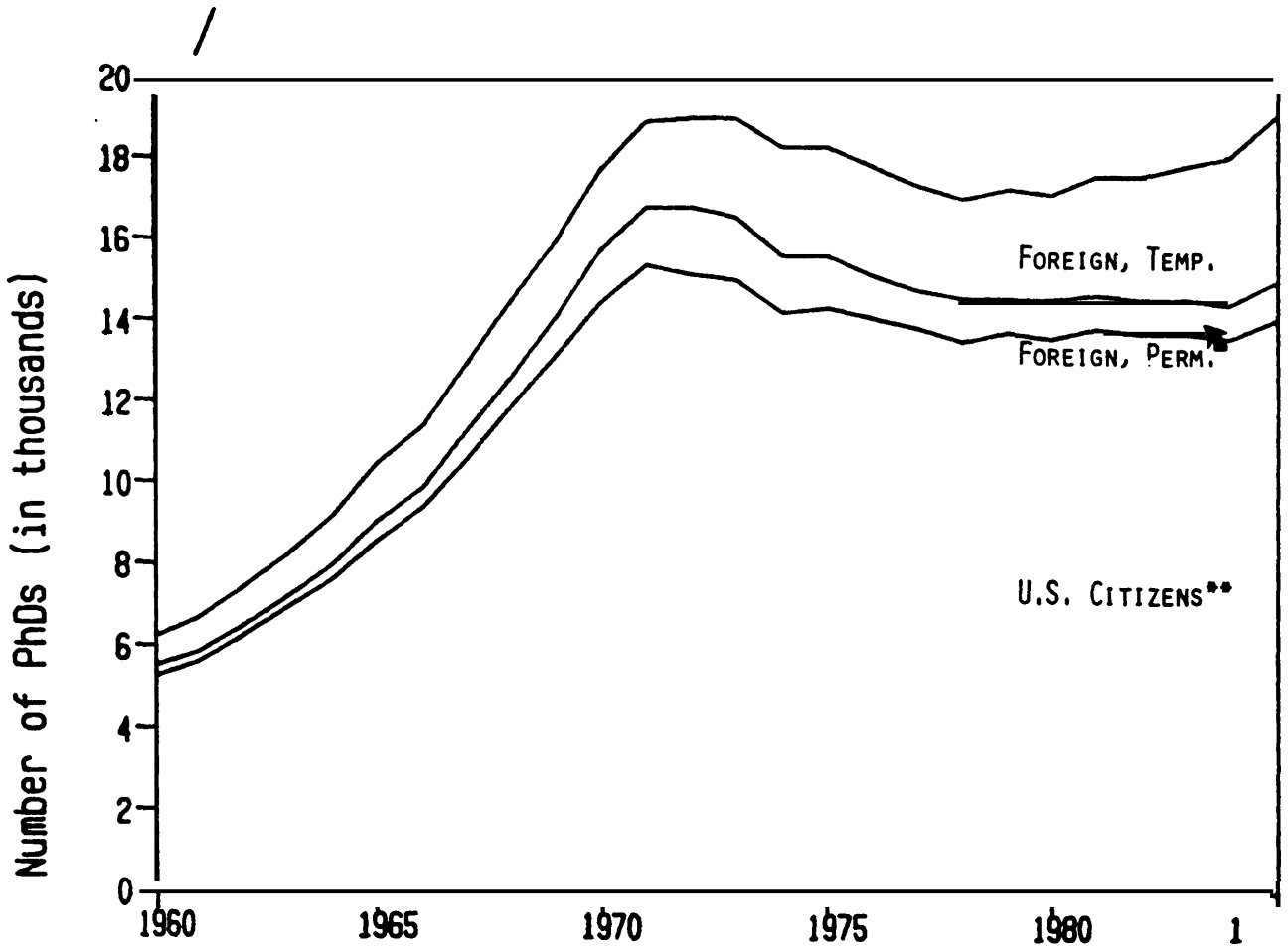
*Percent of U.S. citizens + Foreign. Perm. Visa

Source: National Research Council

in the social sciences. Ph.D. awards to Women in engineering, life, and physical sciences continued upwards. Women receive two out of three psychology bachelor% degrees and over half of psychology and health sciences Ph.D.s, but only 5 percent of physics Ph.D.s and 7 percent of engineering Ph.D.s. Among graduate students, women are twice as likely as men to be in the life sciences or social/behavioral sciences. In engineering, women tend to concentrate in industrial, chemical, petroleum, and electrical engineering. In all fields, women are more likely than men to be unemployed, underemployed, or working part-time; they are also paid less than men with equivalent experience and credentials. In colleges and universities they are less likely to be tenured or on the tenure track. Gender-stereotyped career expectations and differential treatment of women in traditionally male fields continue to deter their participation.

10. Blacks, Hispanics, and American Indians are affected by a variety of socioeconomic factors that lead to weak academic preparation for a science or engineering major and difficulty remaining in the science and engineering pipeline. Black participation has been chronically depressed in science and engineering. They are more underrepresented than Hispanics or American Indians and have made fewer gains over the past 5 years. In all science and engineering fields and at all junctures in the educational pipeline, blacks are the least likely to goon for further education. Less than lo percent of employed black scientists have a Ph.D., compared to nearly 20 percent of white and 30 percent of Asian scientists. Black engineers have slowly increased over the last 10 years, but still represent only 2 percent of the B.S. degrees and employed engineers. Hispanics and American Indians have shown a similar slow but steady increase in their share of B.S. engineering degrees.

11. Despite their minority status, Asian-Americans have attained a strong presence insolence and engineering and continue to make rapid gains. Asians continue to outpace all others (including whites)in science and engineering participation. Most Asian scientists and engineers, if not foreign citizens, are foreign-born or first-generation



*SCIENCE/ENGINEERING **INCLUDES UNKNOWN CITIZENSHIP SOURCE: NATIONAL RESEARCH COUNCIL

immigrants. The high profile and rapid gains of Asian scientists and engineers are skewed towards engineering, the mathematical and computer sciences, chemistry, and physics. The most rapid growth is in engineering. There are twice as many employed Asian-American engineers as there are Asian-American scientists; one-third of the science and engineering Ph.D.s awarded to Asian-Americans are in engineering, compared to just over 10 percent for Hispanics, less than 10 percent for whites, and less than 4 percent for blacks. Asians are more likely to continue on for higher degrees than any group.

12. The increasing presence of foreign nationals is most visible in academic engineering. Foreign nationals are about one-third of all engineering graduate students, more than 40 percent of full-time graduate students, and just under half of recent Ph.D.s. A paucity of American Ph.D. engineers has made universities particularly dependent upon new foreign Ph.D.s to fill faculty teaching and research positions. The high profile of foreign nationals among engineering graduate students, teaching assistants, and faculty raises questions about the quality of teaching in, and attractiveness of engineering for, American students. Foreign students have received a steady 7-9 percent of B.S. engineering degrees since the mid-1970s. In the sciences, foreign students are approximately 15 percent of all graduate students, but the proportion varies widely by field. In 1985, foreign students were much more likely than American students to be pursuing full-time graduate work. Most foreign graduate and postdoctoral students hold temporary visas. About half of graduate foreign engineers stay on to work in the United States, at all degree levels.

A NOTE ON DATA

The field profiles that follow are based on sources that specialize their data analysis and reporting in various ways. This inevitably leads to inconsistencies in definition and methods of counting, be it students enrolled, degrees granted, or scientists and engineers employed. There has been no attempt to reconcile these differences. If estimates differ, this document reports the range and cites the sources. Where systematic differences exist that render one source preferable to another, that source has been used.

The main sources of primary data on scientists and engineers are the National Science Foundation (NSF), Department of Education% National Center for Statistics (NCS), the National Research Council (NRC), the Bureau of Labor Statistics (BLS), the Bureau of the Census, and professional societies. For degree data, NCS provides the only time series at the bachelor% and master% levels; NSF reorganizes these data for reporting purposes. At the doctorate level, the most reliable data are collected by NRC. NSF data begin in 1960; some NRC data go as far back as the 1920s.

Definitions

Some definitions are in order. Foreign nationals can be broken down into those on temporary and those on permanent visas. The latter are equivalent in status to U.S. citizens, and few in number. Most foreign nationals are students or professionals on temporary visas. Many of these protract their stay in the United States for several years through extensions of visas as students: a minority goon to gain permanent visa status.

Minorities fall into two distinct groups. The first are those who are underrepresented in science and engineering relative to their proportion in the U.S. population. These include blacks, Hispanics, and American Indians. They have made few

or no inroads into science and engineering over the past decade. The second groups Asian-Americans, earn science and engineering degrees at a rate above the national average and represent a growing proportion of the science and engineering work force.

Even within these two minority groups, there are significant differences between men and women and among minorities of different national origin, especially among the many Asian cultures. Quantitative analysis of these differences is still limited, however, and will not be discussed in depth in this paper.

Employment

The most comprehensive estimates unemployment come from the National Science Foundation and Bureau of Labor Statistics. BLS reports employer-based data, whereas NSF uses characteristics of the employee: field of highest degree, field of primary work, and self-identification. NSF reports not only employment, unemployment, and underemployment,* but also the type of work that employed scientists and engineers do. NSF reporting generates three groups:

- the total science and engineering work force (including the employed and unemployed);
- employed scientists and engineers (about 98 percent of the total work force, as scientists and engineers have a very low unemployment rate); and
- employed scientists and engineers working in science and engineering jobs.

Discussion and data in this" report generally refer to the last group, scientists and engineers currently employed in science and engineering jobs (primarily research and

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* NSF% definition of underemployment includes those who are involuntarily in non-science or engineering jobs or working part-time but seeking full-time employment. NSF adds unemployed and underemployed rates to define an "underutilized" segment of the work force. In 1986, 6.5 percent of scientists and 2.3 percent of engineers were 'underutilized."

development (R&D) teaching, consulting, R&D management, computing, production, and inspection, according to NSF definitions). This is the active science and engineering work force.

Nearly all employed engineers, but only about three-quarters of employed scientists, are in the active science and engineering work force. For scientists, however, the proportion employed in science or engineering jobs varies widely, from over 95 percent for ocean scientists and physicists to less than 65 percent for economists. Overall, 22 percent of employed scientists are working outside of science or engineering. These people constitute a reservoir of talent. This may reflect excess supply, underutilization, changing career interests or demand that pulls scientifically-trained people into non-science jobs. It should be noted that the definition of a science or engineering job is open to liberal interpretation and subject to the vagaries of self-reporting. As a result, NSF employment data may mask people fulfilling several responsibilities, as well as those not directly working in science or engineering but using their technical training in their work.

Preliminary 1986 estimates of employment and work activity provided by NSF are used in the present profiles. NSF's Division of Science Resources Studies maintains the Scientific and Technical Personnel Data System (STPDS) to report national characteristics of the U.S. science and engineering work force in 27 fields. NSF publishes these data biennially; the 1986 data included here will be published in mid-1987. The STPDS consists of a model that projects changes in the science and engineering work force using field-specific historical growth rates. In addition, several special surveys are conducted, the results of which are used to identify significant deviations in historical growth rates among the fields and characteristics of each. Where appropriate, survey results are incorporated into the STPDS model.

Many professional societies collect extensive data on education, degrees, and employment. In some cases this supply and demand information is limited to individual

or institutional members, while in others data collection spans the entire field. Professional society data in engineering and physics, for example, are both more current and perhaps more accurate than Federal agency data. Source and data idiosyncrasies are discussed below.

Physical Sciences

Professional societies compile detailed degree and employment information in physics, chemistry, and the geosciences. American Chemical Society data correlate well with Federal sources; American Institute of Physics degree figures are consistently higher by as much as 25 percent. The earth and environmental sciences have been treated differently over time and by different sources. The American Geological Institute collects data on enrollments and degrees by subfield of geoscience.

Mathematical and Computer Sciences

Computer science is still closely linked in theory and tools of research to the older field of mathematics. Before 1980, combining data into a single reporting category, as **NRC** has done for research support, may provide a more accurate picture of supply and demand characteristics than do the separate accounts used today.

Reliable data on the separate field of computer science begins around 1980. Data on computer science degrees are uncertain and inconsistent, principally because the relative youth of the field means that most practitioners earned their highest degree in some other field. In addition, there are discrepancies in categorizing mathematics, computer theory, computer and information science, and electrical/computer engineering degrees.

Estimates of the computer science labor force are only slightly better than educated guesses. There is no accepted definition of a computer scientist. NSF and BLS each report about **450,000** in the occupational category ‘computer specialists,” although

their estimates are based on independent definitions and data. NSF "computer specialists" include self-identified computer and systems analysts as well as computer scientists. Consequently, these estimates significantly overstate the actual number of computer scientists, as the bulk of "computer specialists" are systems analysts. There are no hard and fast rules for distinguishing between someone who uses and maintains computer systems and a computer scientist, or between a senior programmer and a systems analyst. Computer programmers and operators are reported separately. NSF is revising its definition of computer scientist.

The National Research Council reports the 1985 computer science Ph.D. labor force — those who have received doctorates in computer science — to be 3,100 strong. However, the number of Ph.D.s working in computer science is much larger, 13,500 in 1985 (NRC, unpublished data) because so many scientists and engineers with Ph.D.s in other fields have migrated into the young and booming field of computer science.

The Computer Science Board, consisting of the chairmen of university computer science departments, has sponsored surveys of academic computer science and engineering research and graduate education since the early 1970s. Similarly, the American Mathematical Society annually collects data on mathematics faculty, employment, graduate enrollments, doctorate awards, and research and education support. The Conference Board on the Mathematical Sciences, an umbrella organization, also undertakes special data collection and analysis with outside project support.

Life Sciences

Data problems are particularly vexing in the life sciences. A consistent taxonomy of fields does not exist. The NSF'S employment and activity estimates of life scientists do not permit easy comparison with its data on life science doctorate degrees. NRC's classification of life science Ph.D. fields differs from the NSF classification. Many of the Ph.D. specialties have no common undergraduate program base, making it difficult to track undergraduate and graduate degree trends.

This lack of consistency is unfortunate. The life sciences constitute a large field: one in five of all scientists in science and engineering positions in 1986 are life scientists. In addition, the life sciences receive large amounts of Federal R&D funds. Of the more than $5 billion in Federal obligations to universities for R&D in 1983, the life sciences received over half, most of which was awarded by the National Institutes of Health (NIH). Lastly, the life sciences as research fields are considered to be especially robust with theoretical and empirical developments emerging at a fast pace.

The profiles of the life sciences presented here have been structured to be consistent with the work force and activity classification system used by the National Science Foundation. NSF divides the life sciences into three groups — biological sciences, agricultural sciences, and medical sciences. Several implications of this should be noted. The medical sciences include research specialties and work activities in the health and medical fields not directly involved inpatient care. The agricultural sciences do not count agricultural economics, which is considered a social science when NSF reports doctorate data. Lastly, in order to be more or less consistent with NSF% work force estimates, we consider in this paper certain Ph.D. degree specialties included as biological sciences by NRC as medical/health specialties.

A related but different approach developed by the Committee on National Needs for Biomedical and Behavioral Research Personnel of the Institute of Medicine deserves mention. Responsible for making recommendations concerning the allocation of training awards under the provisions of the National Research Service Awards Act of 1984 (Public Law 93-348 as amended), the Committee produces a well-respected biennial report that addresses the need for biomedical and behavioral research personnel, the specialties requiring additional personnel, and the kind of training required. The Committee analyzes trends and makes its training recommendations using a field classification that organizes doctorate specialties into clinical science, basic biomedical science, behavioral science, health services research, and nursing research. In doing so, the Committee has assembled enrollment, degree, training, and employment data covering a 20-year period.

Finally, the Committee has devised novel methodologies for examining the supply and demand issues associated with these fields. It provides important information concerning the outlook for psychologists who constitute the core of its broad field, ‘behavioral sciences." The Committee’s analysis of the basic biomedical sciences is an important contribution to understanding the dynamics operating in research specialties of primary concern to NIH.

Social and Behavioral Sciences

Comparing degree and employment data turns on what counts as asocial science. Although economics and psychology are the largest subfields and are typically reported separately within the broad category of "social sciences,” fields such as "urbanstudies" or "history" are arbitrarily included or excluded by data-collection organizations. The criteria used by NSF and BLS to estimate employment yield predictable disagreements. A psychologist employed as a computer scientist is, according to BLS, a computer scientist. NSF will count that same person as a psychologist if he or she holds a psychology degree and identifies himself or herself as a psychologist. Another data source is the American Psychological Association, which collects extensive data on the employment characteristics of its members.

Engineering

Accurate estimates of the size of the work force, or the proportions in different engineering specialties, are difficult to come by. BLS and NSF data on the engineering work force have consistently diverged, with BLS estimates historically higher than NSF's. In recent years, this pattern has been reversed. A related problem exists with engineering technology and technician degrees. NCS reports 4-year technology degrees separately; the Engineering Manpower Commission (EMC) of the American Association of Engineering Societies provides more current reports on Bachelor of Technology and

engineering bachelor% degrees. Associate degrees are reported by both NCS and EMC, but the numbers do not match. The American Electronics Association, an industry organization, does occasional data collection and projections of employment trends in electrical engineering based on employer estimates.