Chapter 1

Overview and Findings

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BACKGROUND AND RATIONALE FOR THIS STUDY

The key role of the Federal Government in educating and assuring an adequate supply of scientists and engineers has been acknowledged since the close of World War "II.[1] It was reemphasized in a series of reports from the President's Science Advisory Committee in the immediate post-Sputnik (1958 to 1962) era which, according to one analyst,[2]

> . . . articulated the national need for greater numbbers of scientists and engineers . . ., and for stronger federal support for the training of manpower for basic research and for university level teaching.

The current Administration has reaffirmed the Federal commitment to the education and training of scientists and engineers, stating that:[3]

> . . . we have to make sure that we derive educational and training advantages from federally supported research—because all of our expectations and opportunities for industrial progress call for a growing supply of skilled technical personnel.

The Task Force on Science Policy of the House Committee on Science and Technology finds that "many of the changes in educational and manpower demands are related in a significant way to general developments in the rates of birth and retirements. " It believes that "these broad, demographic changes, if prudently used in connection with other data, might well provide insights that help anticipate future changes in enrollments and related developments. "[4] To better understand whether demographic trends could be used to help anticipate changes in the requirements for education and training of scientists and engineers, the Committee asked OTA to carry out a study of "Demographic Trends and the Scientific and Engineering Work Force. " As part of that study the Task Force on Science Policy recommended that OTA examine the effects of the "growing interest on the part of women and minorities" in pursuing scientific careers and the "barriers to such participation and the means for lowering them.'" This report is presented as OTA's response to the Committee's request, and as its contribution to the national dialog on this important aspect of Federal science policy.

[1] See Henry A. Moe, Chairman, "Report of the Committee on the Discovery and Development of Scientific Talent, " in Vannevar Bush, *Science- The Endless Frontier,* Office of Scientific Research and Development (Washington, DC: U.S. Government Printing Office, July 1945), pp. 135-186.

[2] Susan Fallows, "Federal Support for Graduate Education in the Sciences and Engineering, 'r background paper prepared for the Ad Hoc Committee on Government-University Relationships in Support of Science, National Academy of Sciences, 1983, p. 5.

[3] U.S. Congress, House, "Testimony of Dr. George A. Keyworth, Director, Office of Science and Technology Policy, Executive Office of the President, " 1983 *Science and Technology}' Posture Hearing With the Director of the Office of Science and Technology Policy,* Committee on Science and Technology, 98th Cong., 1st sess., Feb. 3, 1983 (Washington, DC: U.S. Government Printing Office, 1983), p. 15.

[4] U. S. Congress, House, *An Agenda for a Study of Government Science Policy,* report by the Task Force on Science Policy, Committee on Science and Technology, 98th Cong., 2d sess., Serial MM (Washington, DC: U.S. Government Printing Office, 1985), p. 30.

[5] Ibid,, p. 31.

THE SCIENCE AND ENGINEERING WORK FORCE

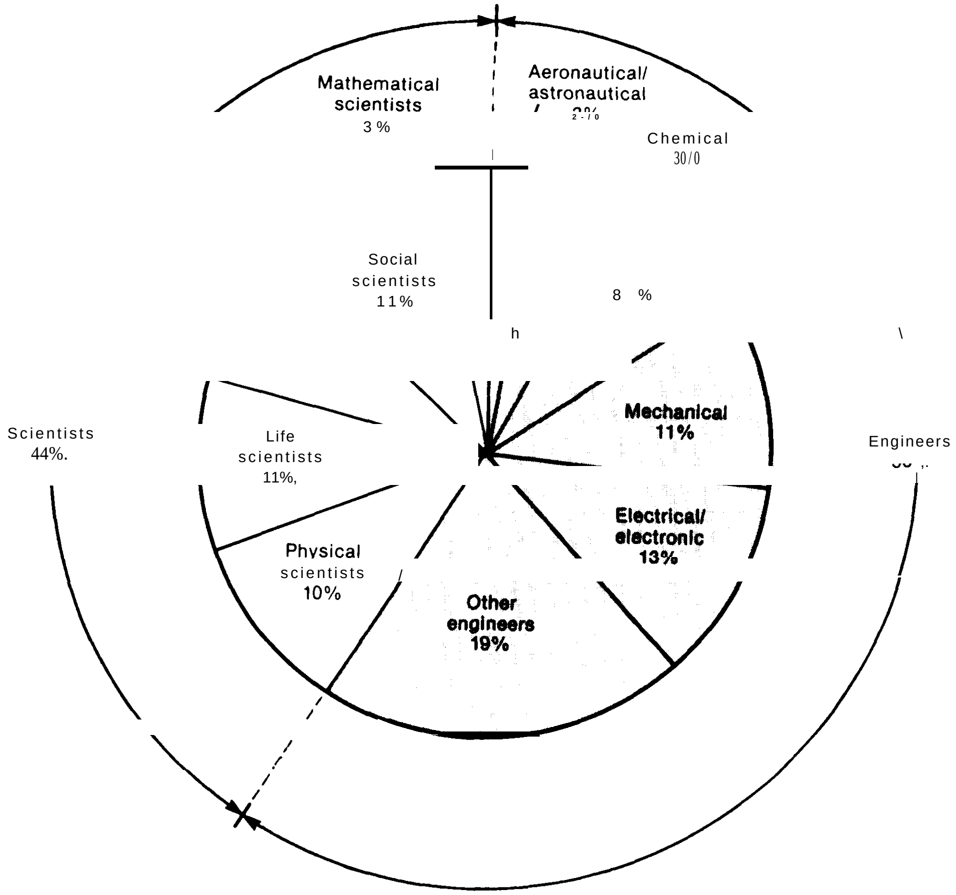
Scientists and engineers represent 3 percent of the national work force, but are considered by many to be a crucial element in the Nation's efforts to improve its economic competitiveness and national security. Professor Karl Willenbrock of Southern Methodist University expressed *this sentiment* quite vividly in hearings on "Scientists and Engineers: Supply and Demand" before the Science Policy Task Force of the House Committee on Science and Technology:6

> The nation's economic vigor and quality of life, as well as military security, are strongly dependent on the number and quality of the engineers and scientists which the U.S. has available both now and in the future. Thus, the health and well-being of the system which educates American youth in engineering and science, and enables the practicing engineer and scientist to stay at the forefront of rapidly developing fields of science and technology is a crucial part of the nation's science policy.

'U.S. Congress, House, "F. Karl Willenbrock, Testimony, " Committee on Science and Technology, Science Policy Task Force, July 10, 1985, p. 1.

Employed scientists and engineers numbered 3.5 million in 1983, an increase of 50 percent from 1976. During that same period the national employed labor force only increased by 11 percent. The scientific and engineering work force is quite heterogeneous in its composition. Fifty-six percent of the total are engineers, predominantly electrical and electronic engineers (13 percent); mechanical engineers (11 percent); and civil engineers (8 percent), The remaining 44 percent are scientists, 11 percent each in the life and social sciences; 10 percent each in the physical and computer sciences; and 3 percent in the mathematical sciences. Figure 1-1 presents the breakdown of the science and engineering work force by field. Among the scientists, one in five has completed the full doctoral training that is generally considered neces-

Figure I-l.—Population of U.S. Scientists and Engineers by Field, 1983



SOURCE National Science Foundation, *Science and* Technology Resources, NSF-85-305, January 1985, pp 53-65 sary for a research career. Nearly half hold only a bachelor's degree and a third have been educated to the master's level. Engineers are even more heavily concentrated at the bachelor's and master's level, as can be seen in figure 1-2.

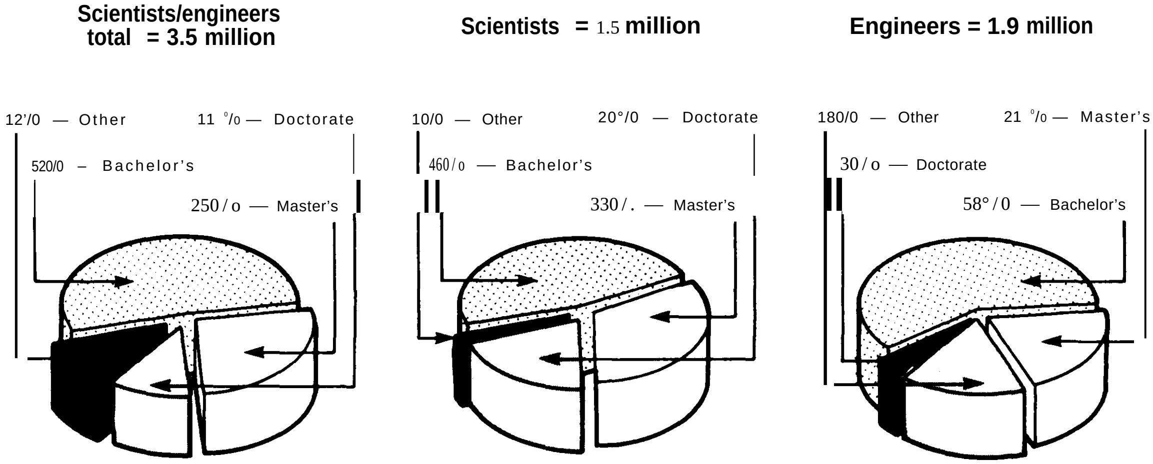
More than 80 percent of the Nation's engineers are employed in business and industry, with 12 percent in government and only 3 percent in education. The scientists are somewhat more evenly distributed among the three employment categories, with 51 percent in business and industry, 17 percent in government, and 24 percent in educational institutions (see figure 1-3 for more details).

Eighteen percent of the scientists, but only 4 percent of the engineers, list research as their primary work activity. Thirteen percent of the scientists, but only 2 percent of the engineers, list teaching as their primary activity. Development, by contrast, is the principal work activity of 30 percent of the engineers but only 9 percent of the scientists (see figure 1-4).[7]

The racial, sexual, and ethnic composition of the scientific and engineering work force is also

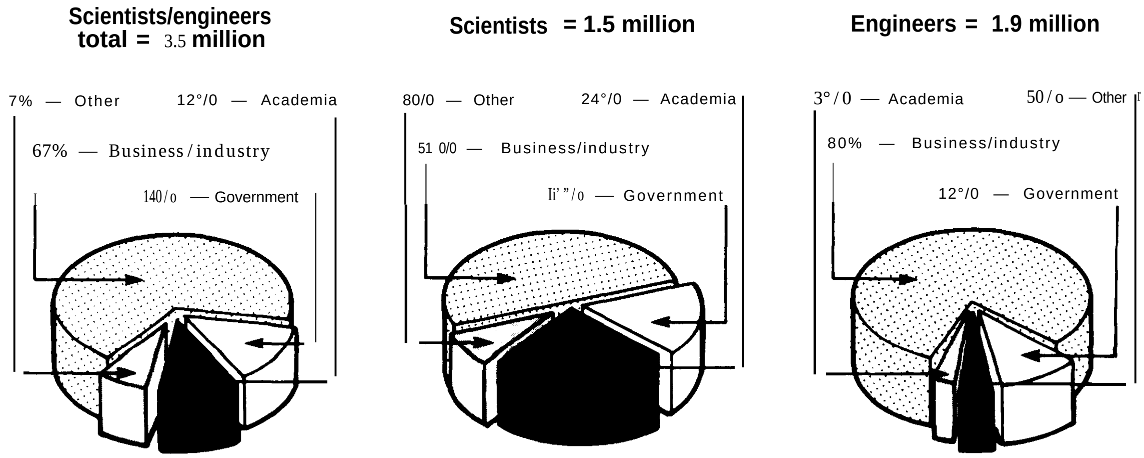
[7]*Science and Technology Resources,* NSF 85-305 (Washington, DC: National Science Foundation, January 1985), pp. 53-65.

Figure 1-2.—Employed Scientists and Engineers by Highest Degree, 1983



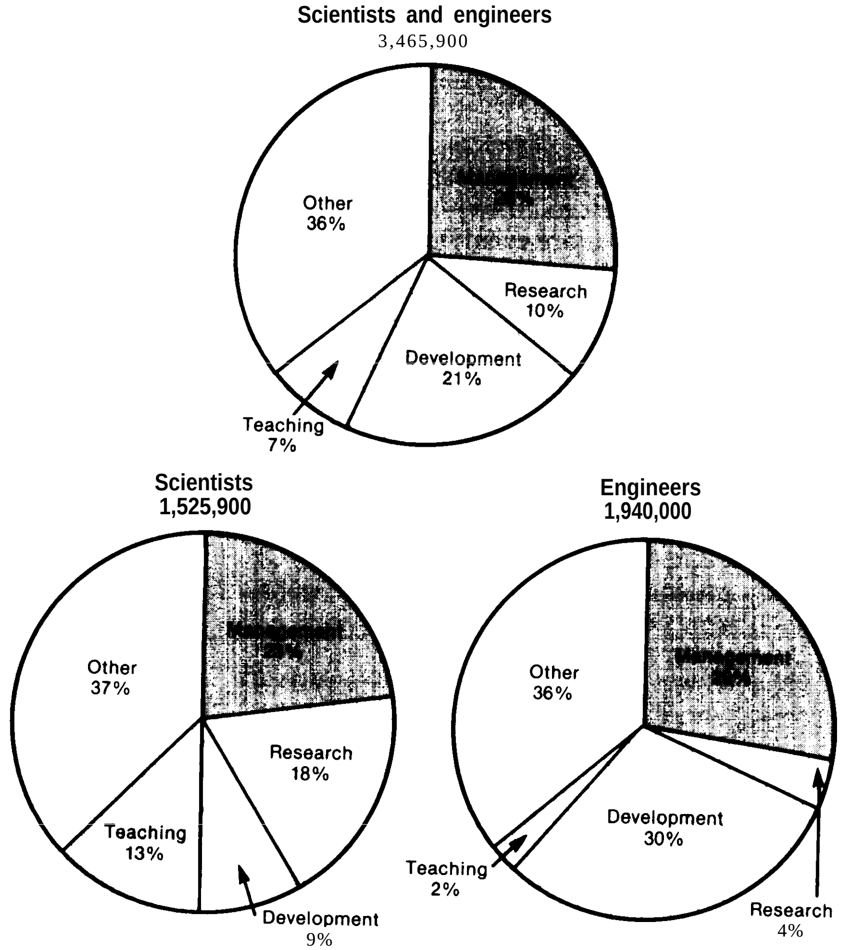
SOURCE National Science Foundation, Science and Technology *Resources,* NSF 85-305, January 1985, pp 53-65

Figure 1-3.—Employed Scientists and Engineers by Sector, 1983



SOURCE National Science Foundation Science *and Technology Resources* NSF 85-305, January 1985 pp 53-65

Figure 1-4.—Employed Scientists[a] and Engineers by Primary Work Activity, 1983



[a]Includes social scientists and psychologists

SOURCE. National Science Foundation, *Science and Technology Resources*, NSF 85-305, January 1985, pp 53-65

quite complex and varied. Blacks, who constitute 10.4 percent of the national labor force, only constitute 2.6 percent of the scientists and engineers, ranging from a high of 6 percent of the social scientists to a low of 0.6 percent of the environmental scientists. Hispanics, who are 5.5 percent of the total labor force, represent only 2.3 percent of the Nation's scientists and engineers. At the other extreme, Asians, who constitute 1.6 percent of the national labor force, make up 4.5 percent of the science and engineering work force.

Women make up 43.5 percent of the civilian labor force, but only 13.1 percent of the scientists and engineers. They are especially well represented in the mathematical sciences (45.8 percent) and psychology (40.9 percent), and especially poorly represented in engineering (3.5 percent) and physical science (11.7).[8] There is concern that the low participation rates of women, blacks, and Hispanics in science and engineering reflect not only tastes and preferences but also social and cultural barriers to equal opportunity in those fields.

[8]*Professional Women and Minorities*, 5th ed. (Washington, DC: Scientific Manpower Commission, August 1984), p. 96.; *Statistical Abstract of the United States*, 1985 (Washington, DC: U.S. Department of Commerce, Bureau of the Census, 1985), pp. 391, 392.

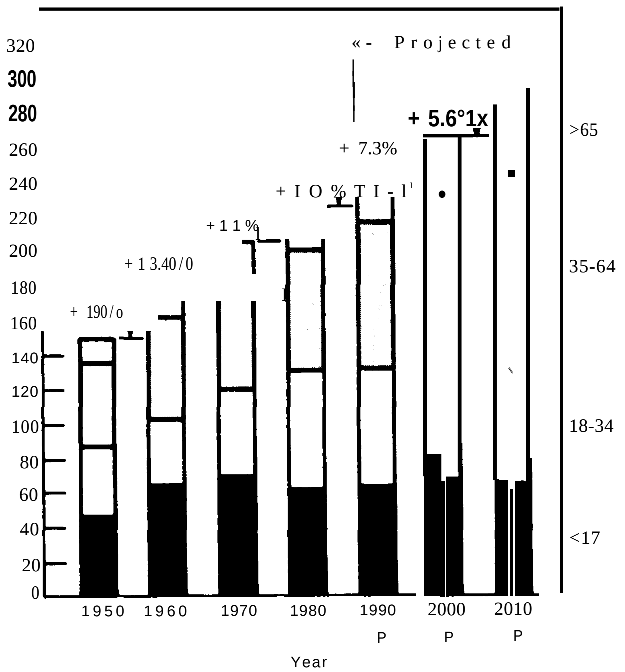
DEMOGRAPHIC TRENDS AND THE POSSIBILITY OF FUTURE SHORTAGES

The U.S. population grew from 152 to 234.5 million between 1950 and 1983, and is projected to increase to 283 million by the year 2010.[9] The rate of growth has slowed dramatically, from 19 percent between 1950 and 1960 to 11 percent between 1970 and 1980, and a projected 5.6 percent between 2000 and 2010. Within that overall growth, different sub populations have experienced very different patterns of change, as can be seen from figure 1-5.[10] The school age and preschool populations (from birth to 17) grew rapidly between 1950 and *1970,* and have essentially leveled off since. The college and university age population (18 to 34) underwent significant expansion between 1960 and 1980, will contract in size again between 1990 and 2000, and then expand somewhat between 2000 and 2010. The senior working age population, 35 to 64 years old, will expand dramatically in size between 1980 and 2010, as will the total number of elderly people, aged 65 and over.

[9] *Projections of the Population of the United States, by Age, Sex and Race: 1983 to* 2080, Series P-25, No. 952 (Washington, DC: U.S. Department of Commerce, Bureau of the Census, May 1984), table E, p. 7. See also, *Statistical Abstract of the United States,* 1985, op. cit., table 27, p. 26.

[10] *Projections of the Population,* op. cit., table E, p. 7.

Figure 1-5.—U.S. Population by Major Age Group 1950-2010



SOURCE *Projections of the Population of the United States, by Age, Sex and* Race 1983 *to* 2080, series P-25, No 952 (Washington, DC U S Department of Commerce Bureau of the Census, May 1984), table E, p 7

Figures 1-6 and 1-7[11] display these population changes in somewhat greater detail. They show the percentage of the population in each age group in every fifth year from *1950* to 2000 and the year 2010. By following the bars from left to right on each graph one can trace the effects of the "baby boom" of the post World War II era on each population group. The successive peaks in population—1960-70 for the 5 to 13 year olds; 1975-85 for the 18 to 24 year olds; 1990-2000 for the 35 to 44 year olds—are exhibited, as are the subsequent dramatic declines in the percentage shares of the different groups following the "baby boom, " and the rather modest "baby boom echo" of the early 1980s.

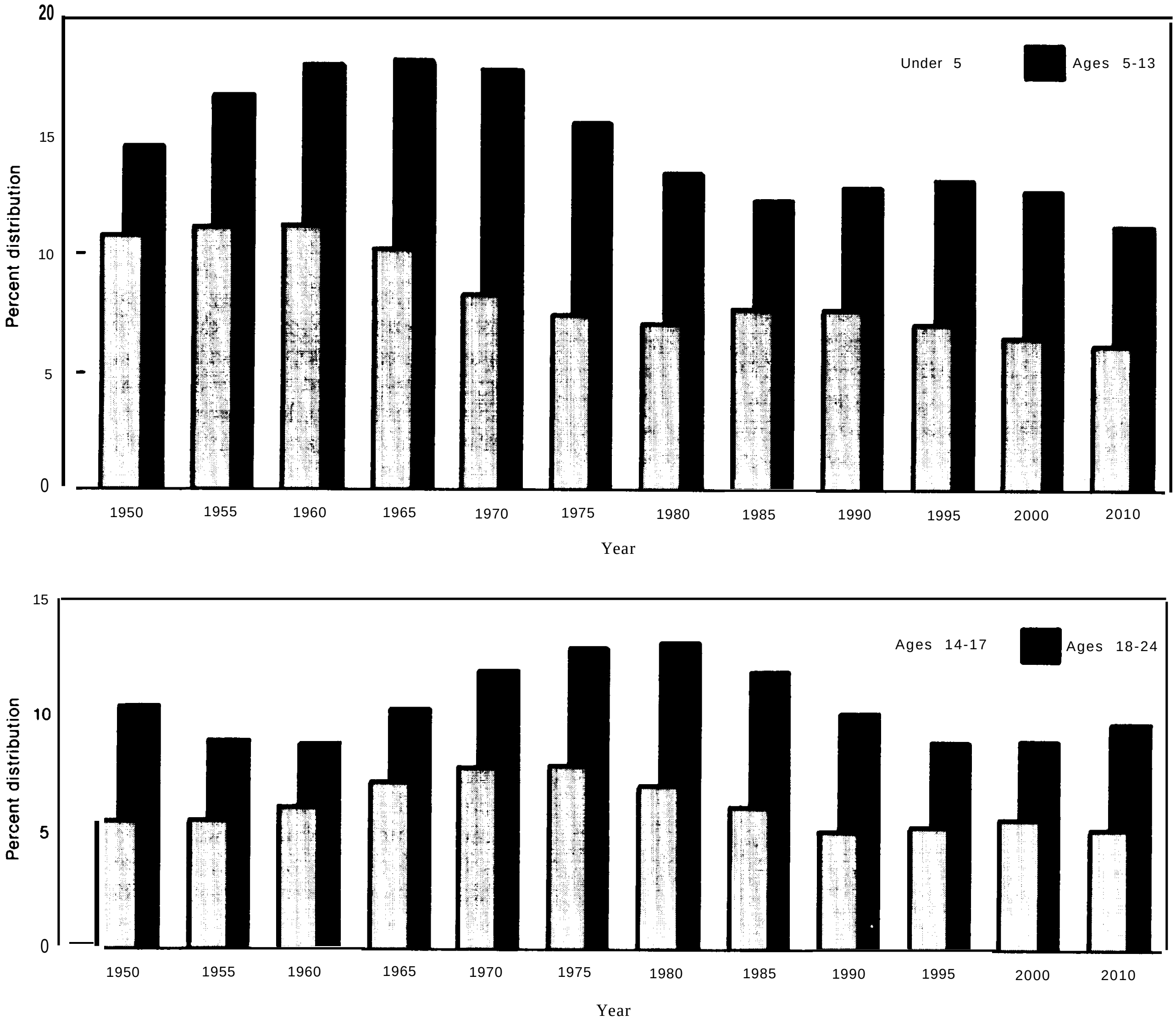
The groups of concern in this essay are the 18 to *24* year olds and the 25 to 34 year olds, the two subpopulations that contribute in greatest numbers to undergraduate and graduate enrollments. Therefore, it is worth looking at the demographic trends for these two subgroups in somewhat greater depth. Figure 1-8[12] presents the population trends for 18 to 24 and 25 to 34 year olds over the 1950-2010 time period. The figure shows the dramatic increase in the former group between 1955 and 1980, doubling from 15 to 30 million in that period. It shows as well the 23-percent decline projected for the 1980-95 time period, followed by an 18-percent increase between 1995 and 2010. For the 25 to 34 year old group, there is a doubling in the 1965-90 time frame followed by a decline of 16 percent between 1990 and 2000.

Each year about 300,000 college seniors, or 30 percent of the graduating class, receive their bachelor's degree in a science or engineering field.

[11] Ibid., table F, p. 8.

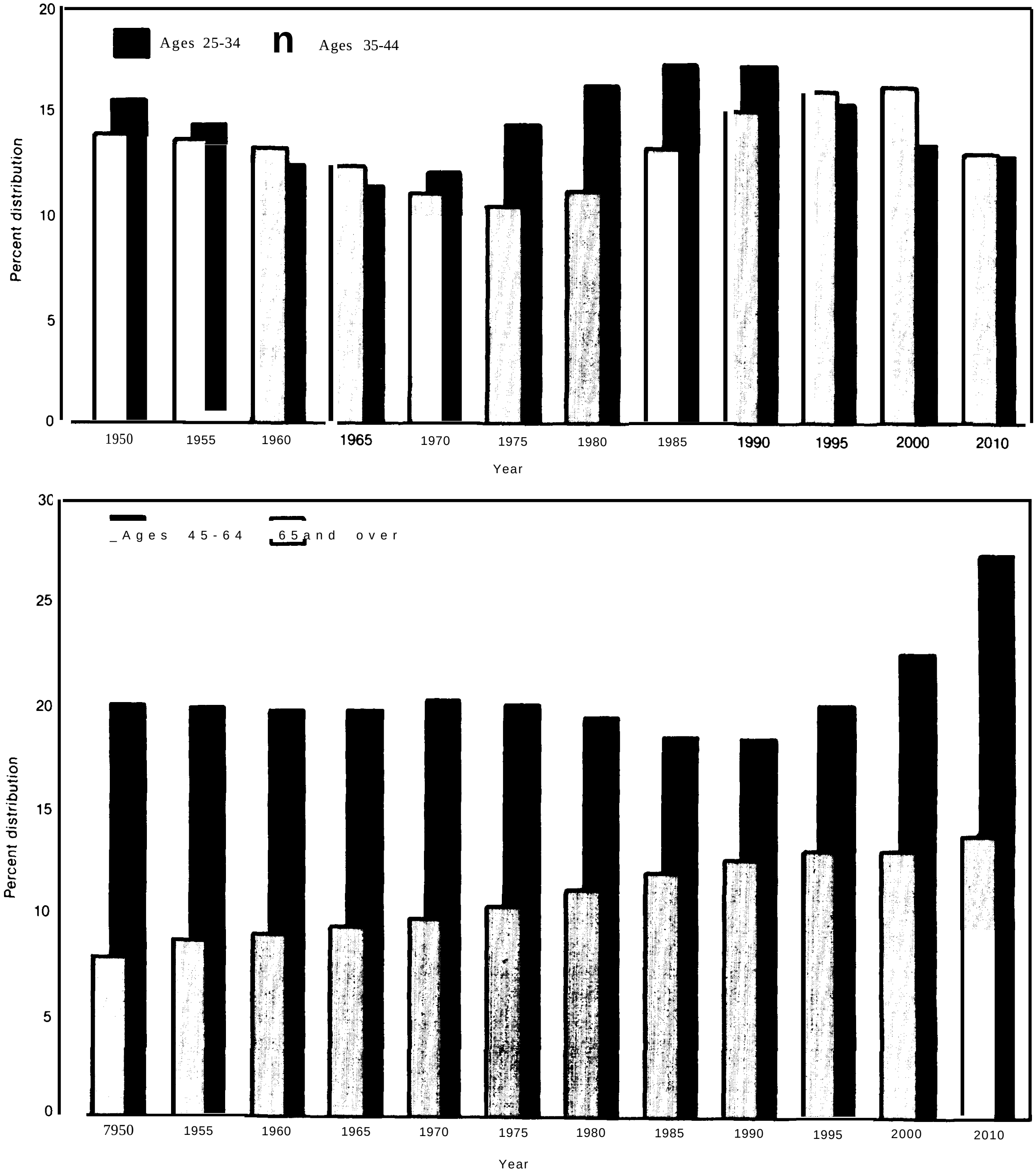
[12] Ibid., table E, p. 7.

Figure I-6.—Population Distribution by Age, 1950-2010



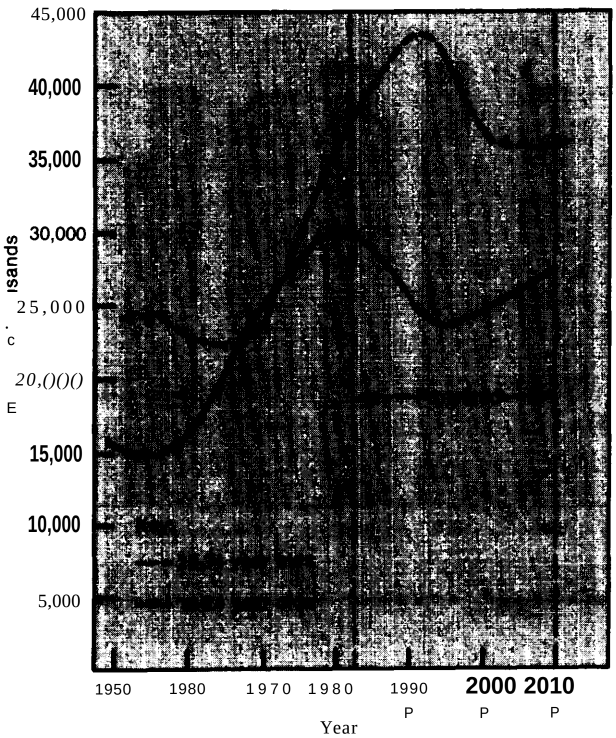
SOURCE *Projections of the Population of the United States, by Age, Sex arid Race 1983 to 2080,* series P-25, No 952 (Washington, DC U S Department of Commerce, Bureau of the Census, May 1984), table F, p 8.

Figure I-7.—Population Distribution by Age, 1950-2010



SOURCE *Projections of the Population of the United States, by Age, Sex and Race 1983 to 2080*, series P-25, No 952 (Washington, DC U S D@ partment of Commerce, Bureau of the Census, May 1984), table F, p 8

Figure I-8.—18-24 Year Olds and 25-34 Year Olds in the U.S. Population, 1950-2010



NOTE: Figures for 1983 to 2010 are projected.
SOURCE *Projections of the Population of the United States, by Age, Sex and Race 1983 to 2080*, series P-25, No 952 (Washington, DC. U S Department of Commerce, Bureau of the Census, May 1984), table E, p 7

This overall level has remained nearly constant for close to a decade, but there have been dramatic fluctuations among fields (see examples on p. 21).[13] Science and engineering masters degrees have remained relatively constant in the 53,500 to 56,500 per year range since 1972, with social science and engineering each accounting for more than 25 percent of the total. The number of science and engineering doctorates peaked at 19,000 in 1972 and has fluctuated between 17,000 and 18,000 **a year since** 1976.[14] (See figures 1-9, 1-10 and 1-11.[15])

The relatively constant rate of production of scientists and engineers over the past decade could be significantly affected by the projected decline in the college age population in the near future. Labor market specialists estimate that the decrease in 18 to 24 year olds discussed above could lead to a drop in college enrollments of 12 to 16 percent between now and 1995.[16]

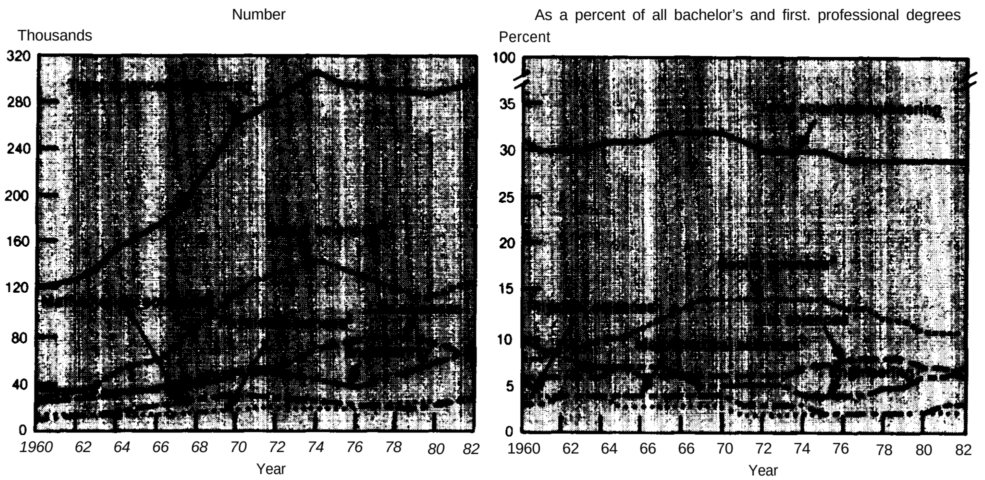
[13] *Science and Technology Resources, Op. Cit.*, pp.73-74.

[14] *Science and Engineering Personnel: A National Overview*, NSF 85-302 (Washington, DC: National Science Foundation, 1985), pp. 154-156.

[15] *National Patterns of Science and Technology Resources, 1984*, NSF 84-311 (Washington, DC: National Science Foundation, 1984), pp. 29-30.

[16] *Research Excellence Through the Year 2000* (Washington, DC: National Research Council, Commission of Human Resources, 1979), pp. 12-15; William Bowen, *Report of the President* (Princeton, NJ: Princeton University, April 1981), pp. 11-15.

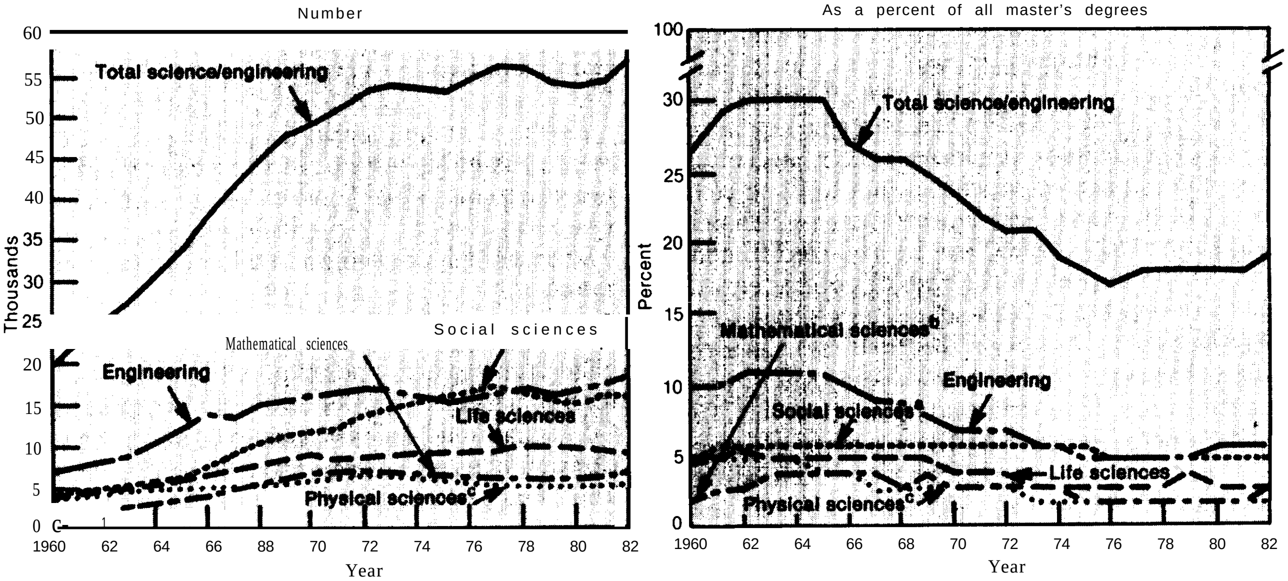
Figure 1-9.—Science/Engineering Bachelor's and First-Professional Degrees Awarded by Field



[a]Includes psychology
[b]Includes computer science
[c]Includes environmental science

SOURCE National Science Foundation, *National Patterns of Science and Technology Resources*, NSF 84-311, 1984, pp 29 and 30

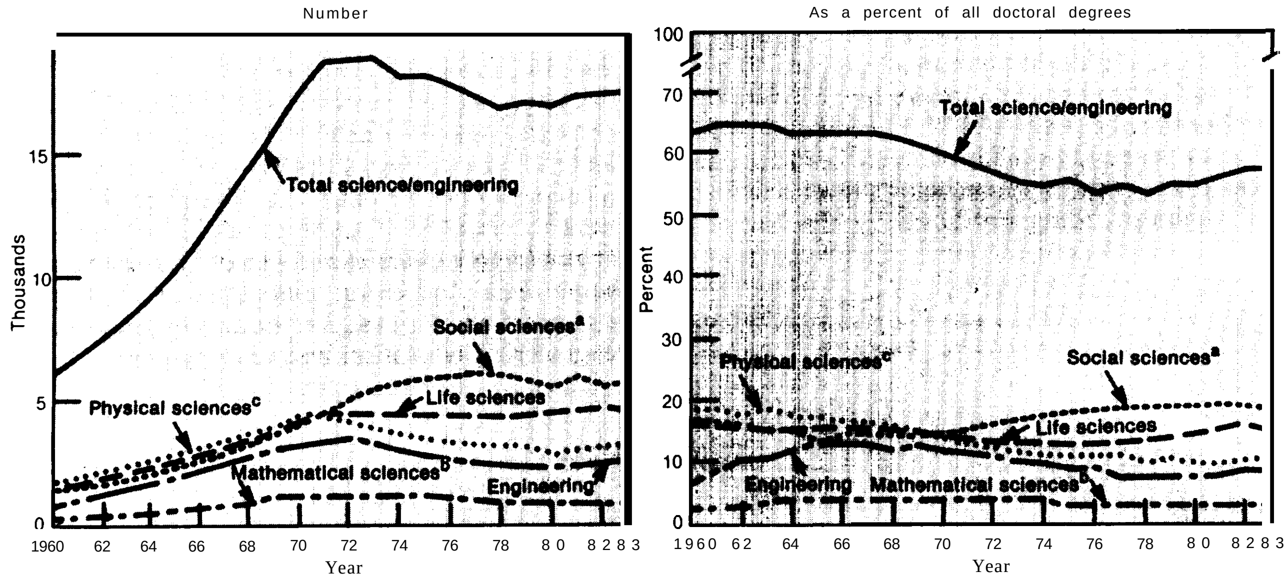
Figure 1.1O.– Science/Engineering Master's Degrees by Field



[a]Includes psychology
[b]Includes computer science.
[c]Includes environmental science

SOURCE National Science Foundation, *National Patterns of Science and Technology Resources.* NSF 84-311 1984, pp 29 and 30

Figure I-II.—Science/Engineering Doctorates Awarded by Field



[a]Includes psychology
[b]Includes computer science
[c]Includes environmental science

SOURCE National Science Foundation *National Patterns 01 Science and* Technology *Resources* NSF 84-311 1984 pp 29 and 30

In addition to these changes in the overall numbers, there will be qualitative changes in the student mix that could affect science and engineering. The percentage of minorities in the 18 to *24* year old cohort will increase from 20 to about 27 percent by 1998,[17] so the increasing participation of blacks, Hispanics, Asian Americans, and other minorities in higher education that took place in the 1970s (minority enrollments increased 86 percent from 1972 to 1982) can be expected to continue. (The decline in the rate of college enrollment among black high school graduates since 1978 casts some doubt on this prediction as it relates to the black community.) These groups, with the exception of Asian Americans, have historically participated less actively in science and engineering education than the majority population. The numbers of women, part-time students and students in 2-year institutions all increased by about 70 percent in the decade from 1972 to 1982, approximately twice as rapidly as the overall increase in higher education enrollments .18 These groups also participate in science and engineering education at lower rates than their white male full-time counterparts at 4-year colleges and universities.

Assuming that science and engineering degrees continue to represent no more than 29 to 30 percent of the total baccalaureates awarded in any year, as they have since 1972, the decrease in the 18 to 24 year old population could lead to a decline in the number of bachelor's level scientists and engineers being produced by the Nation's higher education system of a corresponding 15 percent by 1995. Similarly, the decline in 25 to 34 year olds projected for the 1990-2000 time frame could lead to a possible decrease in the number of science and engineering doctorates produced in that time period. (The master's degree has considerably less meaning in science and engineering than it does in other fields, such as business, social work, and education, so it will not be discussed at any length in this technical memorandum.)

"*Statistical Abstract, 1985,* op. cit., pp. 26-34.
[18] *Digest of Education Statistics,* 1983-1984 (Washington, DC: National Center for Education Statistics, 1984), p. 98.

To investigate the likelihood of this possible decline taking place, and its possible consequences for the Nation's scientific and technical enterprise, OTA examined the historical record on the relationship between science and engineering degrees and demographic trends and on the labor market for science and engineering baccalaureates and Ph.D.s in industry and academia. OTA also reviewed recent projections of supply and demand for scientists and engineers, consulted extensively with scientific and engineering labor market specialists and carried out a number of independent studies and simulations on its own. OTA's findings from its investigation of science and engineering personnel issues are presented below. Findings 1 to 3 deal with population trends and the education and employment of science and engineering baccalaureates and Ph. D.s, Findings 4 to 6 deal with projections of supply and demand, and the functioning of the labor market for technical personnel. Findings 7 to 10 examine the barriers to equality of opportunity in science and engineering careers experienced by women and some racial and ethnic minorities, and the special problems of foreign nationals in science and engineering education and employment.

FINDINGS

Finding 1

Population trends, although important, do not **have as great an impact on the supply of scientists and engineers as do career choices and mar**ket forces.

Less than 7 percent of the members of a given age cohort currently receive a bachelor's degree in a science or engineering field. Less than 0.5 percent achieve the doctorate in one of those fields. 1[9] These very small percentages imply that changes in the overall size of the age cohort should have far less of an effect on the number of scientists and engineers produced in a given year than var-

"*Science and Technology Resources,* op. cit., pp. 74 and 78; *Projections of the Population,* op. cit., table 5, p. 38.

iations in the rate at which students choose to enter those fields. A slight increase in the rate of selection of science and engineering careers among college age students could more than compensate for the decline in 18 to 24 year olds projected for the 1982-95 time frame. For example, if the rate of attainment of science and engineering bachelor's degrees were to increase from the 1982 level of 6.8 percent of the 22 year old population to the 1973 level of 8.2 percent, [20] that would cause a rise in the number of degrees awarded in these fields of *20* percent.

Less than two-thirds of those receiving science and engineering baccalaureates in recent years have actually become part of the science and engineering work force. The National Science Foundation (NSF) conducted a survey of science and engineering bachelor's degree holders in *1982* to determine the experience of the classes of 1980 and 1981 in making the transition from school to work. It found that only 43 percent of the science and engineering baccalaureates from those 2 years were employed in a science or engineering field a year or two later .2* An additional 21 percent were enrolled in graduate school full time, although not necessarily in science or engineering. Twenty-eight percent *were* employed outside of science and engineering, 5 percent were unemployed and seeking employment, and 4 percent were outside the labor force. Thus, less than two-thirds of the 1980-81 science and engineering baccalaureates were actually in the science and engineering work force a year after graduation. This percentage varied from a low of 43 percent in the social sciences to a high of over 80 percent in engineering, computer science, and the physical sciences, with mathematics and the life sciences directly in the middle, at *70* and 67 percent, respectively.

There is, moreover, no national market for scientists and engineers as a group. Rather, there are individual markets for graduates trained in particular disciplines, and these markets and disciplines experience very different conditions at the same time. For example, there is currently alleged to be an 8 percent vacancy rate in engineering faculty positions at a time when new Ph. D.s in sociology, mathematics, and other fields are having trouble finding university employment.[22] NSF projects that the demand for electrical and aeronautical engineers and for computer specialists could exceed the supply of graduates in those fields by as much as *30* percent over the 1981-87 time frame, while at the same time there will be significantly fewer openings for biologists, chemists, geologists, physicists, mathematicians, chemical, civil, and mechanical engineers than there will be trained degree holders .23 Nearly 28 percent of the science baccalaureate holders in 1981 obtained employment outside of science and engineering in the same year that 40 percent of the firms responding to an NSF survey reported shortages of engineers.[24] ***Thus, it is individual disciplines, especially those linked with high growth or defense-oriented industries, which could experience problems; not "science and engineering" as a whole.***

This finding is encouraging, because individual disciplines have shown great ability to grow and shrink as market conditions require. The number of engineering baccalaureates, for example, more than doubled between 1976 and 1984.[25] The number of bachelor's degrees in computer and informational science tripled between 1977 and 1982. At the same time those in education, foreign languages, anthropology, history, and sociology all fell by 30 percent or more.[26] Thus, college **students appear to be highly responsive to market signals, and appear to shift their career choices dramatically toward fields that promise greater occupational rewards.**[27] Engineering and computer science have been highly marketable

[20] *Science and Engineering Degrees:* 1950-1980, NSF 82-307 (Washington, DC: National Science Foundation, 1982), p. 60.

[21] *National Patterns of Science& Technology Resources, 1984*, op. cit., p. 24,

[22] Michael S. McPherson, "The State of Academic Labor Markets, " November 1984, draft, p. 5. To be published in B.L. R. Smith (cd,), *The State of Graduate Education* (Washington, DC: The Brookings Institution, 1985).

[23] *Projected Response of the Science, Engineering and Technical Labor Market to Defense and Nondefense Needs: 1982-1987,* NSF 84-204 (Washington, DC: National Science Foundation, 1984), p. 43.

[24] *National Patterns of Science and Technology Resources, 1984,* op. cit., p. 24.

[25] *Engineering Education and Practice in the United States* (Washington, DC: National Research Council, 1985), p. 57; and *Manpower Comments* (Washington, DC: Scientific Manpower Commission, January-February 1985), p. 34.

[26] McPherson, op. cit., table 1.

[27] Sue E. Berryman, in an exhaustive study of "The Adjustments of Youth and Educational Institutions to Technology Generated

majors over the past 5 to 10 years, as measured by the numbers of job offers and level of starting salaries for bachelor's degrees in those fields. Foreign languages, history, sociology, and anthropology, by contrast, are all fields that have experienced relatively weak job markets in the past decade.

Finding 2

Levels of graduate enrollment and Ph.D. production in science and engineering appear to be largely independent of general demographic trends.

Between 1960 and 1970 the number of full-time graduate science and engineering students enrolled in U.S. institutions of higher education increased 150 percent, from 78,000 to 188,000.[28] The number of science and engineering Ph.D.s awarded increased 183 percent, from 6,300 in 1960 to 17,700 in 1970.[29] At the same time the population of 22 to 34 year olds—the group that supplies the majority of graduate students—increased only 18 percent .30

Between 1970 and 1982 the situation changed dramatically. Graduate enrollments in science and engineering increased by only 36 percent; annual doctorates awarded decreased by 1 percent, but the graduate school age population increased by more than 50 percent. Thus, **there is no evidence of a direct relationship between graduate enrolments and Ph. D.s in science and engineering, and changes in the graduate school age population.**

The dramatic expansion in Ph.D. production and graduate enrollment in science and engineering that occurred in the 1960s was apparently related to four simultaneous developments. First, Federal support for graduate education in general, and science and engineering education in particular, grew enormously in that decade. The number of Federal graduate fellowships and traineeships increased from 8,000, of which 5,000 were in science and engineering in 1960, to 52,000, of which 36,000 were in science and engineering in 1969. The number of research assistantships in science and engineering increased from about 5,000 in 1954 to over 15,000 in 1969.[31] At the same time Federal support was expanding, State and institutional aid to graduate education, especially in the form of teaching assistantships, also increased dramatically, to more than 50,000 graduate students in 1969.[32]

In addition to increased Federal and State support for graduate education there was a third factor, a surging demand for Ph.D.s, especially in academia, in that era. The number of junior faculty openings exceeded the number of doctorates awarded by 50 percent (260,000 openings; 170,000 doctorates) between 1961 and 1970.[33] (See figure 1-12.[34]) In addition, the Federal research

Changes in Skill Requirements, " Research Report Series, RR-85-08 (Washington, DC: National Commission for Employment Policy, May 1985), finds that "young people generally are responsive to changing market signals; they alter their fields of study, increase or decrease the amount of time they spend on formal education, and are very mobile both geographically and occupationally" (p. i,),

[28] Fallows, op. cit., p. 10.

[29] Ibid., p. 11.

[30] *Statistical* Abstract *of the United States, 1979* (Washington, DC: U.S. Department of Commerce, Bureau of the Census, 1979), pp. 160 and 29.

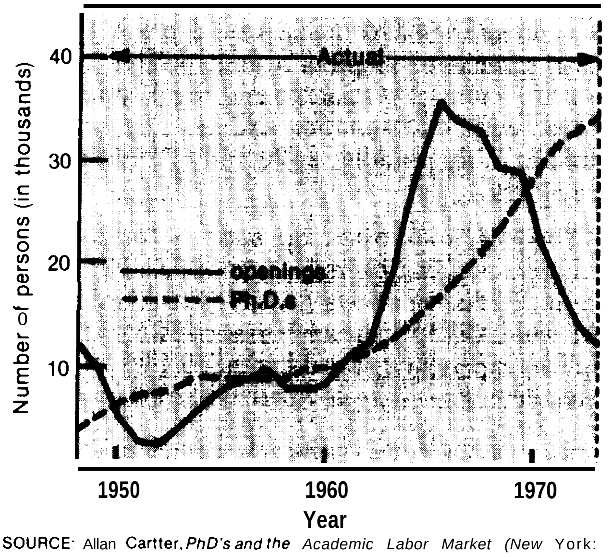
[31] Federal Interagency Committee on Education, "Report on Federal Predoctoral Student Support, " April 1970, tables 1-10. R.G. Snyder, "The Effectiveness of Federal Graduate Education Policy and Programs in Promoting an Adequate Supply of Scientific Personnel, " contractor report prepared for the Office of Technology Assessment, June 1985, p. 14.

[32] Snyder, op. cit., p. 18.

[33] Allan Cartter, *Ph.D.s and the Academic Labor Market* (New York: McGraw-Hill, 1976), p. 143.

[34] 1 bid., p. 129.

Figure I-12.—Comparison of Junior Faculty Openings With Earned Doctorates Awarded (actual 1948-73)



SOURCE: Allan Cartter, *PhD's and the Academic Labor Market* (New York: McGraw. Hill, 1976), p 129 and development (R&D) budget quadrupled in that decade, creating a sizable demand for doctoral scientists and engineers as researchers.

Finally, popular opposition to the Vietnam War led many male college graduates to enroll in graduate school to avoid the draft.

In the 1970s, when the growth in academic demand and Federal R&D funding slowed, the military draft ended, and the level of Federal support for graduate fellowships and traineeships decreased dramatically, Ph.D. production began to fall. It fell most rapidly in those fields where Federal fellowships and traineeships and R&D funds declined most severely (i.e., engineering, mathematical sciences, and physical sciences).

Finding 3

A combination of faculty and student demographics will lead to a weak academic market for new Ph. D.s over the next decade, followed by an upsurge in academic hiring between *1990s* **and** 2010.

The projected decline in student enrollments discussed above, coupled with a low retirement rate among current faculty (most of whom were hired in the late 1960s and will not retire until the late 1990s), will lead to a very weak academic market for new Ph. D.s in the next decade. This decline was predicted by a number of scholars in the 1970s, and has been confirmed by analyses carried out this year by OTA and the National Academy of Sciences. ” According to the OTA analysis, the total academic demand for new science and engineering doctoral degree recipients should average about 3,000 to 6,000 per year from 1983 to 1998. This is less than one-third the annual number of new Ph. D.s projected for the period under the assumption that such degrees will remain constant at about 18,000 per year, and 40 to 80 percent of the rate of hiring for new science and engineering Ph. D.s in academia that existed in the 1978-83 time frame (about 8,000 new hires per year). After 1998 the demand for new science and-engineering faculty and research personnel in academia should increase substantially, due to increases in both enrollments and retirements.

[6] National Research Council, *Forecasting Demand for University Scientists and Engineers: Proceedings of a Workshop* (Washington, DC: National Academy of Sciences, 1985), p. 1.

According to OTA analysis, the academic demand for new science and engineering Ph. D.s could be roughly the same from 1998 to 2013 as the level of hiring that took place during the 1970s. The pattern of decline followed by increase will be experienced separately over the next quarter century by each of the major science and engineering fields. (See chapter 3 for the analysis that supports these projections.)

The trends discussed above pose two significant policy-related questions. First, should steps be taken now to increase the demand for new Ph. D.s during the decline decade of 1988 to 1998, in order to smooth out the hiring pattern over the next quarter century and prevent potential graduate students from becoming discouraged from pursuing a research career due to the weak near term academic market? The National Institutes of Health (NIH) system for training and supporting biomedical research personnel appears to be an example of a self-conscious and explicit Federal personnel policy in an important scientific field that could be emulated elsewhere. Consistent Federal support for biomedical research in terms of funding of research and training has produced both a substantial supply and demand for investigators. This has created a steady-state system in which there have been no major shortages of biomedical personnel, although some analysts believe there to be a surplus of biomedical Ph. D.s today. However, it is a large system which would be difficult to reduce in significant ways without major dislocations.

Unlike most other fields of science, there is an institutional feedback mechanism between NIH and the Institute of Medicine (IOM) that ensures a periodic assessment of the status of biomedical research personnel. This represents, to some extent, informed decisionmaking in the implementation of research training programs. The current number of trainees is quite close to the number recommended by the IOM committee. Allocation of Federal support to either predoctoral training or postdoctoral training is a method of fine tuning that can potentially be used to control the supply of biomedical investigators. (See appendix A for an in-depth analysis of Federal education and manpower policies with respect to biomedical personnel.)

Second, in the expansion period of 1998-2013, will the combined requirements of industry and academia for science and engineering Ph. D.s exceed the annual supply? The number of science and engineering Ph. D.s employed in industry has grown at the rate of 8 percent per year over the past decade.[36] If this rate of growth continues, the industrial demand for new science and engineering Ph. D.s could exceed 10,000 per year by the first decade of the 21st century. The combined academic and industrial demand for new science and engineering Ph. D.s could then exceed the level of Ph.D. production for that period.

Finding 4

Long-term projections of supply and demand for scientists and engineers in the economy as a whole are inherently unreliable.

Apart from academia, where known demographic trends exert considerable influence on the demand for new faculty, long-term projections of demand for scientists and engineers in the overall economy are fraught with uncertainty and are relatively unreliable. Such projections depend on assumptions about the future behavior of variables such as GNP growth, defense spending, technological change, and Federal and industrial R&D expenditures, which themselves are not known with any degree of certainty. Unexpected changes in any of the input variables can cause major inaccuracies in the projections. For example, the Bureau of Labor Statistics (BLS) projects the requirements for different occupations 10 and 15 years into the future, and provides an "early warning" to high school and college students through its annual *Occupational Outlook Handbooks,* which are distributed to guidance counselors. Labor economist Lee Hansen took the projections made by BLS in 1960 and 1965 for the number of engineers that would be required in different disciplines in 1975 and 1980, and compared them with the actual numbers that were employed in those years.[37] He found that BLS overprotected the requirements for aeronautical, civil, and mechanical engineers by 20 to 55 percent. The errors were caused by the understandable failure of the BLS to anticipate the cutback in Federal R&D expenditures in the early 1970s and the recession in the mid-1970s. However, the BLS overprojections would have lead analysts to overestimate the growth component of the annual demand for engineers between the early 1960s and the late 1970s by 120 to 600 percent.

Projections of supply are equally problematic. It is extremely difficult to predict the career choices of undergraduates or graduate students, or their responsiveness to changes in demand in technical fields. In the absence of such a predictive capability, analysts in the past tended to assume the continuation of existing trends, an assumption which can lead to gross inaccuracies. For example, in 1967 NSF, extrapolating from existing trends, projected there would be 30,500 doctorates awarded in science and engineering in 1975.[38] The actual number turned out to be 17,784. A large number of scientific "manpower" analysts in the late 1960s and early 1970s made similar errors for the same reasons. In the absence of a causal model that can accurately predict changes in career selection patterns, any supply projections are no better than educated guesses.

Given the problems of projecting supply and demand, predictions of shortages or surpluses based on such projections are not likely to be very reliable. This is not, however, a serious problem, for reasons that are discussed in the next two findings,

Finding 5

Labor markets adjust to supply-demand gaps.

Most projections of shortages assume tacitly that demand and supply are independent, so that there can be no adjustment to projected supply-demand gaps. This assumption makes sense, however, only under certain very *restrictive* conditions:

1. that demand for the final product is relatively unaffected by labor costs;
2. that supply is not appreciably affected by wage changes; and
3. that the skill shortages are unique, in that workers possessing them cannot be replaced

[36] *Characteristics of Doctoral Scientists and Engineers in the United States,* NSF 85-303 (Washington, DC: National Science Foundation, 1985), table 2, pp viii and ix.

[37] *labor Market Conditions for Engineers: 1s There a Shortage?* (Washington, DC: National Research Council, 1984), pp. 89-92.

[38] *The Prospective Manpower Situation for Science and Engineering Staff in Universities and Colleges: 1965-1975* (Washington, DC: National Science Foundation, 1967), p. 16.

by workers from other occupations or by new technology.

If any of these conditions are violated, then a projected supply-demand gap can be closed by market adjustment. These conditions are very restrictive: They apply to only a few limited sectors, such as some parts of the defense industry and certain startup firms that require highly specialized personnel.

The essence of a labor market is that it adjusts. A projected gap between supply and demand usually does not indicate an impending shortage, but rather that some sort of adjustment must take place. The adjustment can be made either by employees or employers, or both. On the employees' side, an increasing number of entry level professionals can become trained in the shortage area, or experienced workers from neighboring specialties can move into the shortage occupation. On the employers' side, they can offer higher salaries; increase their search and recruiting efforts; rearrange jobs to utilize the available skills, education, and experience more efficiently; or make larger investments in internal training and retraining of their existing work force. Cutting back output, or the level of research and development, due to personnel shortages is probably the response of last resort.

Labor market and scientific "manpower" specialists consulted by OTA agreed that it is more important to try to understand the process of adjustment of the technical labor market to supply-demand imbalances than it is to make long-term projections. There can be significant problems with labor market adjustments that need to be understood by policymakers. For example, although students shift their career interests to follow signals from the marketplace, as we have seen above, this response is not a short-term remedy to a supply-demand gap because it takes 4 years to train a new engineer and 6 years (from the baccalaureate) to train a Ph.D. scientist. In a fast-moving market, the needs of employers may change by the time entering students graduate. This lag effect is especially powerful for occupations that are subject to sudden unanticipated surges in demand, as in the semiconductor and computer industries in recent years. In addition, universities may not be able to provide sufficient resources to meet new demands on their curricula, as has recently been the case in engineering. Both universities and students may misjudge the direction of the marketplace, leading to further misallocation of resources.

Occupational mobility from related fields is the short-term response to a shortage. The primary concern about occupational mobility from the employer's point of view is that it may lower the quality of work or require expensive retraining. From a societal point of view, however, occupational mobility appears to have served the Nation well in meeting its needs for technical personnel. The Manhattan project in World War II, the Apollo program in the 1960s, the environmental and energy programs of the 1970s, and the rapid buildup of the semiconductor and computer industries all relied successfully on the importation of scientific and technical talent from related fields. Many analysts consider the mobility and adaptability of the Nation's scientific and engineering work force to be one of its greatest strengths.

Employer adjustments, such as extensive searches and retraining of personnel from related fields, involve considerable costs. For example, one analyst estimates that the cost of recruiting a new engineer can run *as* high as 1 year's salary. Rearrangement of jobs within the firm can interfere with the distribution of incentives via rank and promotion. Despite these costs, several of the *more* mature computer companies, such as Data General Corp. and Digital Equipment Corp., have adopted systematic training approaches, Faced with a continuing series of shortages, they have shifted from their traditional "buy" to a "make" strategy for obtaining skilled personnel. This helps lower the turnover rate and increases the supply of experienced engineers, who are in short supply.

Finding 6

The Federal role in alleviating potential shortages of technical personnel appears limited to assistance for education and retraining.

OTA carried out an analysis of the labor market in electrical engineering, a profession that has experienced reported shortages in the recent past, is heavily involved in areas of rapid technological change, and faces demand from both the military and civilian sectors of the economy. OTA

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found that the supply of entry level electrical engineers is likely to stay nearly in balance with demand for the foreseeable future, as occupational mobility makes up the difference between the number of entry level engineers needed and the number of college graduates actually holding electrical engineering degrees. However, some educational institutions report that they do not have sufficient resources to train all the potential electrical engineering students who are interested.

The spot shortages of experienced engineers with specific areas of expertise reported in surveys of electronics and computer firms in the recent past will undoubtedly continue. When a particular technology gets "hot," engineers who know the field and can handle the overall design of a project are in great demand. If the technology is new or has not been used extensively in the past, the supply of engineers who combine these attributes can fall short of demand. Unfortunately, these shortages are not of a type amenable to government intervention. The government might be able to help by promoting the retraining of experienced engineers into new startup fields. Mission-agency sponsored R&D programs could conceivably serve that retraining function. The Federal energy and environment programs of the *1970s,* for example, helped retrain significant numbers of engineers to become specialists in those two fields.

As to the effects of increased military spending on the market for electrical engineers, OTA did not find this to be a significant cause for concern. The most definitive short-term projections by NSF[39] indicate that a shift from low to high defense spending would only increase the demand for electrical engineers by 4 to 5 percent, turning a slight shortage into a slightly larger one. In a survey of firms that employ electrical engineers in the Boston area, OTA found that shortages are not perceived to vary much by the level of military procurements. Many respondents felt that the two climates of military and civilian work are so very different that there is low mobility between the two "sectors."

Finding 7

Near-term demographic trends enhance the importance of promoting equality of access to scientific and engineering careers for women and disadvantaged minorities.

The Science Policy Task Force recommended that the study of demographics and the science and engineering work force also examine issues related to the participation of women and minorities in science and engineering careers, with special attention paid to the identification of barriers to participation and means of lowering those barriers.'[40] OTA finds that the changing college student demographics of the coming decade have several important implications for national policy to promote equality of opportunity in science and engineering. Since the number of college graduates will decline substantially, it becomes especially important to utilize all potential human resources to the fullest extent possible. This means that increasing attention should be paid to those groups with historically low participation rates in science and engineering, such as women and some minorities. The increasing fraction of college students that will be drawn from the black and Hispanic populations, which have historically participated in science and engineering education and employment at far lower rates than the white population, imply that programs aimed at increasing the participation of these two minority groups could be an especially important source of new talent.

Finding 8

Gender-stereotyped career expectations and differential treatment of women scientists in the work force are the two major factors discouraging women from entering science and engineering.

The literature on the factors that discourage women from participating in science and engineering careers is extensive and well developed. Two factors stand out as crucial. These are gender-stereotyped career expectations among younger women entering the science and engineering tal-

[39] *Projected Response of the Science, Engineering and Technical Labor Market to Defense and Nondefense Needs: 1982-1987,* op. cit., p. 43.

[40] *An Agenda for a Study of Government Science Policy,* op. cit., p. *31.*

ent pool, and differential treatment of women scientists and engineers in the work force.

Gender-stereotyped career expectations are manifested most dramatically in the major field preferences of college freshmen, where 20 percent of the men, but only 3 percent of the women surveyed in 1984 listed engineering as their field of choice, ” By contrast, only 4 percent of the men, but 21 percent of the women, listed education, nursing, or occupational and physical therapy as their preferred major. In other sciences, women were *more likely* to select a social or biological science major than men, and slightly less likely to be interested in the physical sciences. These differences are often explained as the result of women’s alleged lower preference for or lesser ability in quantitative fields. But the fact that freshmen women select mathematics, accounting, and business at the same rate as men casts doubt on that explanation. Rather, it appears that fields that are heavily associated with “men’s work” tend to be avoided by women, just as fields that are stereotypically associated with women are avoided by men.

A second aspect of gender-stereotyped career planning has to do with girls’ expectations of how they will be able to allocate their time during adulthood between participation in the labor force and work in the home. Sue Berry man finds that “the more that girls expect continuous labor force participation during adulthood, the more their occupational goals approximate those of their male counterparts. ” She also finds that “since career goals seem to determine educational investments, gender differences in occupational expectations become key to understanding gender differences in high school mathematics participation, “[42] a key element in pursuing a science or engineering career. These expectations are in fact derivative of gender stereotyping in the work force as a whole. In our society women are still expected to assume the major role in housekeeping and child rearing, and to sacrifice their professional interests to those of their husband. As long as that situation exists, women will be less likely than men to select occupations like science and engineering that require major educational and labor force commitments. Berry man finds, interestingly enough, that *male single parents* “make occupational and labor force adaptations to parenting that look like the occupational and labor force plans of girls who expect dual family and work responsibilities. ’[43]

Women’s experience in the science and engineering work force is decidedly different from that of men. Women’s attrition rates are 50 percent higher than men’s: in 1982, 25 percent of women scientists and engineers but only *16* percent of men were outside of the science and engineering work force .44 Women’s unemployment rates are significantly higher: 4.5 percent v. 1.9 percent for men. Women’s salaries are significantly lower than men’s in almost all fields of science, in every employment sector and at comparable levels of experience, although recent female entrants to the science and engineering work force are doing considerably better than their more senior counterparts. In academia, men are far more likely than women to hold tenure track positions, to be promoted to tenure, and to achieve full professorships, This holds true even for men and women of identical academic age (number of years since receiving the doctorate), field, and quality of graduate school attended. [45]

The differential treatment of women in the work force most directly violates the principal of equality of opportunity because it affects people who have established, by virtue of obtaining an advanced degree, the right to pursue a scientific or engineering career based solely on the quality of their work. It also has a significant effect on female students in the educational pipeline. A woman student in a department where no women have been hired or promoted to tenure is not likely to form a positive picture of her future employment prospects. Nor will she experience the kind of role model which the literature on equality of

[41] A W Astin et al., *The American Freshman : National Norms for Fall 1984* (Los Angeles, CA: Cooperative institutional Research Program Unit'er>ity of California at Los Angeles, December 1984), pp. 16-18, 32-34

[42] Sue E. Berry 'man, "Minorities and Women in Mathematics and Science Who Chooses These Fields and Why?" May 1985, typescript, p. 14

[43] Ibid.

[44] Ibid., p. 7.

[45] For details see *Women and Minorities in* Science *and Engineering* (Washington, DC: National Science Foundation, January 1984) and *Career Outcomes in a ,11,] tched Sample of Men and Women Ph. D s* (Washington, DC National Research Council, 1981)

opportunity suggests is desirable to assist her in identifying with her future profession. Finally, the higher unemployment and attrition rates among women in science and engineering as compared to men represent a serious waste of human resources cultivated at considerable expense to the Nation and the individual.

Finding 9

Blacks, Hispanics, and American Indians are affected by a variety of socioeconomic factors that lead to poor academic performance and an inability to remain in the science and engineering educational "pipeline."

Blacks, Hispanics, and American Indians receive degrees in quantitative fields at less than half the rate of whites, due to their tendency both to participate in higher education and to select quantitative fields at substantially lower rates.[46] The quality of academic preparedness in secondary schools is cited by many experts as the greatest factor affecting these minorities' academic performance and baccalaureate attainment in college. Greater attrition levels in science and engineering among minorities correlate very highly with poor academic preparedness in high school as measured by grade averages and class rank. Problems with academic preparedness, in turn, appear to be related to socioeconomic factors such as parents' educational levels and social class.

Parents' education appears to be an especially important factor. Students whose parents have obtained college or graduate degrees are more often enrolled in quantitative majors than students who have less well-educated parents. Sue Berryman finds that "being second generation college not only increases, *but also equalizes,* the choices of quantitative majors across white, black, American Indian, Chicano, and Puerto Rican college freshmen."[47] A study carried out for the Departments of Defense and Labor in 1980 found that the strongest single predictor of reading abilities and scores on the Armed Forces Qualifications Test was the mother's educational level.[48] Youths whose mothers had completed eighth grade or less scored in the 29th percentile on the AFQTs. Those whose mothers had completed high school had an average percentile score of 54. Those whose mothers were college graduates averaged 71.

Social class, according to Sue Berryman, "seems to be a proxy for family characteristics that affect school achievement." These characteristics include "the family's press for achievement, language models in the home, academic guidance provided by the home," work habits and activities of the family, and the "nature and quality of toys, games, and hobbies available to the child."[49] These characteristics correlate very highly with children's achievement scores. Later in life, social class correlates strongly with the level of resources a college student can bring to bear on his or her education. Financial problems in college are a factor cited by many analysts in explaining the poor persistence of minorities in the scientific and engineering educational system.

Despite the formidable socioeconomic problems responsible for the low participation rates in science and engineering among blacks, Hispanics, and American Indians, there is considerable anecdotal evidence that well-designed intervention programs can assist these groups in obtaining access to science and engineering careers. The American Association for the Advancement of Science, in an assessment of more than 100 such programs, found them to "have demonstrated that there are no inherent barriers to the successful participation of women and minorities in science or mathematics" if these groups are provided with "early, excellent, and sustained instruction in these academic areas."[50] These programs help stimulate an interest in science and engineering among talented students who might never have considered a career in one of those fields. They also provide supplementary instruction in science and mathematics to help improve the academic preparedness of those students who choose to major in a quantitative field. To date, programs for minorities have not been rigorously and systematically evaluated to determine the ingredients of success and failure. (Programs for women appear to have

[46] Berryman, op. cit., pp. 2-3.

[47] Ibid., p. 17.

[48] Betty M. Vetter, "The Emerging Demographics—Effect on National Policy in Education and on a Changing Work Force," background paper prepared for the Office of Technology Assessment, pp. 4-5.

[49] Berryman, op. cit., p. 15.

[50] Shirley M. Malcom, *Equity and Excellence: Compatible Goals,* Publication 94-14 (Washington, DC: American Association for the Advancement of Science, December 1984), p. viii.

been more carefully studied.) Nor has any attempt been made on the national level to share the lessons learned from successful programs with less fortunate endeavors. NSF could take a leadership role in this area, but thus far it has not done so. In fact, the executive branch's response to the mandate it received from Congress in *1980* to develop a comprehensive program to promote the participation of women and minorities in science and engineering was to cut back or eliminate the few programs in existence in that era. [51]

Despite the problems cited above, women's participation in science and engineering has increased dramatically in all fields and at all levels. There appear to be no inherent reasons why these increases should not continue. For blacks and Hispanics the causes of low participation are so deeply entwined with larger social and cultural factors that the prospects for further improvements without dramatic societal intervention do not appear very bright. Already the rate of increase in participation among these groups has slowed significantly since the dramatic improvements of the mid-1970s.

Finding 10

The increasing participation of foreign nationals in U.S. Science and engineering education has raised a number of unresolved policy issues.

The number of foreign nationals enrolled in American institutions of higher education has increased by a factor of 10 in the past three decades, from 34,000, or 1.4 percent of the student population in 1954, to 338,000, or 2.7 percent of the student population, in 1984.[52] Foreign students tend to enroll proportionately more often in engineering and medical sciences than in humanities and social sciences. This has been attributed *to* the relatively high cost to a developing country of establishing proper training facilities for the engineering and natural science disciplines. A projected increase of 350,000 or more foreign college students over the next decade[53] could compensate to some degree for the expected decline in American 18 to *24* year olds,

Foreign nationals have assumed a large share of both enrollments and doctoral degrees in graduate departments of engineering, mathematics, and computer science (more than 40 percent of enrollments and degrees in engineering; 40 percent of enrollments and 25 percent of degrees in mathematics). There is concern that because science and engineering education is capital intensive, and many science and engineering graduate students are supported by Federal research assistantships, that the United States is subsidizing the training of non-U. S. citizens. However, it appears that many graduate engineering departments would have had to curtail their research and teaching activities substantially without foreign student enrollments. Moreover, analysts Lewis Solmon and Ruth Beddow have found, in a study of 1980-81 foreign degree recipients at the bachelor's, master's, and Ph.D. levels, that "foreign students probably pay more than their education costs, and they might be paying substantially more. "[54] Some also argue that there are foreign policy and good will benefits to U.S. education of foreign citizens. The U.S. Agency for International Development recently announced that it would increase its scholarship support to Latin American students in order to counter Soviet leadership in this area; this may be seen as evidence for this point of view.

There is disagreement between various groups within the United States as to whether individuals admitted to the United States as students who complete a graduate degree here should be allowed to remain here after completion of the degree and perhaps a short period of further training. Increasing proportions of those earning doc-

[51]The National Science Foundation Authorization and Science and Technology Equal Opportunities Act of 1980 (Public Law 96-516, 94 Stat, 3007) required the Director of NSF to prepare and transmit to Congress "a report proposing a comprehensive and continuing program at the Foundation to promote the full participation of minorities in science and technology' (Section 34b). The NSF response to this requirement, 'Proposals of the National Science Foundation to Promote the Full Participation 01 Minorities and Women in Science and Engineering, " Dec. 15, 1981, typescript provided by National Science Foundation, contains the following quote:

> The Foundation's authorizing legislation for fiscal year 1981 provided for several programs that addressed the participation of minorities and women in science and technology. These programs were reduced by rescissions in fiscal year 1981 and were deleted from the Foundation's budget request for fiscal year 1982 as part of the Administration's program for economic recovery.
>
> Two reports required of the President by Section 35 of Public Law 96-516 were never transmitted to Congress.

[52]*Open Doors: 1983 84* (New York Institute of International Education, 1984), table 1.3 p 6.

[53]*'Foreign Student Flows* (New York: Institute of International Education, 1985), pp. 78-79.

[54]Lewis C. Solmon and Ruth Beddow, 'Flows, Costs and Benefits of Foreign Students in the United States: Do We Have a Problem *Foreign Student Flows* op. cit., pp. 121-122.

torate degrees (56 percent in 1983) are remaining in the country after graduation.[55] Many employers, both in industry and in academic institutions, say that they cannot fill certain research and faculty positions with U.S. citizens, and available data verify this.[56] The Institute of Electrical and Electronic Engineers, on the other hand, contends that increasing numbers of foreign engineers earning degrees in this country are taking jobs at low pay in order to remain here, thus driving down salaries and reducing opportunities for U.S. engineers.[57] The limited statistical evidence that exists, however, indicates that foreign engineers are not paid less than comparably trained and experienced U.S. engineers.[58]

Many foreign nationals choose to enter the academic market after graduation, especially in engineering. A 1982 survey found that 18 percent of all full-time engineering faculty members earned their B.S. degrees from an institution outside the United States. Several authors have made reference to a "growing problem" of foreign nationals on engineering faculties. Analysts contend that the drawbacks of an increasingly foreign born faculty are the limitations in their communications skills and difficulties they may have in adjusting their teaching and research styles to the expectations of American culture.[59]

Foreign nationals are often unable to work on industry or government projects with national security or economic competitiveness implications, However, those students that obtain positions in industry after graduation can and often do become U.S. citizens and thereby cease to be "foreign nationals."

Finally, some analysts contend that a lack of data prevents the Nation from making informed policy decisions in this area. However, there is a great deal of information about foreign students available from the Institute of International Education, and several new research projects sponsored by NSF promise to fill many of the gaps. What is most lacking is a consensus over the definition of the "problem."

"*Participation of Foreign Citizens in U.S. Science and Engineering* (Washington, DC: National Science Foundation, January 1985), p. v,

[56] Betty Vetter, "U.S. Education and Utilization of Foreign Scientists and Engineers," contractor report prepared for the Office of Technology Assessment, p. 16.

[57] See statement of Jack Doyle, Institute of Electrical Electronic Engineers, in Scientific Manpower Commission, "The International Flow of Scientific Talent: Data, Policies and Issues," May 7, 1985, p. 29.

[58] Michael G. Finn, "Foreign National Scientists and Engineers in the U.S. Labor Force, 1972 -1982," draft report to the National Science Foundation, March 1985.

[59] *The International Flow of Scientific and Technical Talent*, op. cit.