

Concentration of Degrees in Academic Institutions by Two Measures of B.S. Degrees Produced

	Top 100 Univ.	Next 150 Univ.	Top 100 Colleges	Next 150 Colleges	All 500
1. All NS&E B.S.'s (1982)	40%	27%	10%	10%	87%
2. Those B.S.'s earning NS&E Ph.D.'s (1981-84)	46%	22%	15%	5%	88%

Notes: (1) Universities are ranked by Federal R&D Obligations.

(2) Colleges are ranked by number of graduates earning NS&E Ph.D.'s during 1981-84.

Figure 7

Geographic Distribution of NS&E Degrees

A coarse (four-region) geographic analysis of NS&E B.S. production hints at possible future shifts (Figure 8). Recent graduates have been concentrated in the East and Midwest, regions which the Bureau of Census forecasts to have the biggest decrease in young adults by 1998. Since most college students are enrolled at institutions within a few hours automobile travel from home, Eastern and Midwestern schools may experience declines in enrollment unless special incentives are provided to attract more students from distant states.

Sorting institutions by region and quality gives another perspective (Figure 9). On the basis of entering students' SAT scores in mathematics, most of the public institutions are rated medium. The quality of private schools ranges widely. The largest percentage of high quality private institutions are in the East, and a significant number of the lower quality private institutions are in the South. Predominantly, private institutions in the Midwest and West are of medium quality. As a result of this distribution, the East has the highest percentage of NS&E baccalaureates from high quality institutions (46% vs. the national average of 30%), while the South has the lowest percentage (15%) from high quality institutions.

Regional Statistics

	East	Midwest	West	South
NS&E B.S. degrees in 1982	51,700	51,000	47,500	35,700
Degrees per thousand 22-year-old residents	51	46	43	36
Number of B.S.-granting institutions for NS&E degrees	393	370	281	332
Change in 22-year-olds: 1982-1998	-43%	-35%	+2%	-18%

Figure 8

Distribution of NS&E B.S. Degrees by Region and by Quality of Institution

Region	<u>Quality of Institution</u>		
	High	Medium	Low
East	46%	43%	11%
Midwest	24%	66%	11%
West	31%	58%	11%
South	15%	45%	40%

Quality key: "High" means 40%+ of freshman have math SAT scores of 600+.

"Medium" means 40%+ of freshman have math SAT scores of 500-600.

Figure 9

Sources of Revenue for Higher Education

According to published data from the National Center for Education Statistics, the principal sources of revenue for educational and general expenses (including research, but excluding auxiliary enterprises, independent operations, and hospitals) for both public and private universities and colleges have remained constant for the past decade or more. Private universities and colleges depend primarily on tuition, and public institutions rely primarily on support from state governments. During this period, the Federal Government has contributed around 15% to the universities and about 7% to 4-year colleges (Figure 10). In the aggregate, the Federal Government is not a large factor in academic funding. However, the predominant recipients of Federal R&D funding are the top 100 research universities (with only 1.5% or so going to 4-year colleges). Most of these funds go to public, Doctoral-granting universities (53%), with the smallest amount (0.5%) going to the private colleges.

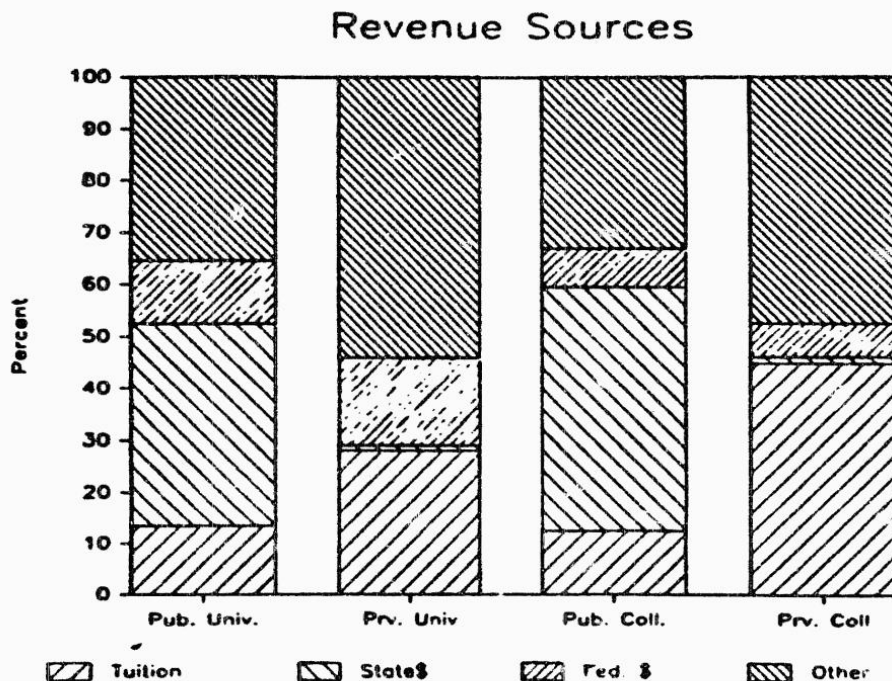


Figure 10

The best of the private colleges appear to have capped their enrollment years ago. They may have realized that the growth in the number of college-age students during the 1970's was a temporary event, which would be reversed in the 1980's and 1990's. Enrollment at these high quality, 4-year colleges (i.e., those 51 colleges with average freshman SAT scores in math above 600) grew by only 4% during the 1970-1983 period. In contrast, there was 60% growth in enrollment at other private colleges and 38% at public colleges. These stringent voluntary enrollment ceilings virtually guarantee that the private, high quality colleges will not experience any significant declines in enrollment in NS&E fields in the future, nor should those private universities that have traditionally attracted high quality undergraduate students.

THE SITUATION TOMORROW

Projections of need and supply of scientists and engineers are problematic. However, those responsible for the health of science and engineering will always need to examine future emerging trends to try to anticipate problems that can be reduced through changes in public resource allocations.

The Demand Side

Those who have estimated the demand for scientists and engineers far into the future agree that we will need more. In the absence of analytically defensible or dependable empirical estimates of future conditions, economic indicators with a relation to the need or demand for NS&E's can be examined and projected into the years ahead. A variety of indicators can be employed. For example, the number of new B.S.-level engineers employed is positively correlated with GNP growth ($R^2 = .78$), and positively correlated with growth in value added in high technology industries ($R^2 = .82$). (In fact, GNP growth and growth in value added in high technology industries are highly correlated, with a simple R^2 of .98.) Other long-term positive indicators of the demand for new engineers are population growth and a growth in the NS&E share of the total U.S. workforce.

The Supply Side

The size of the population base from which NS&E's are drawn yields some information about supply potentials. The number of 22-year-olds in the U.S. has been falling since 1982, and will continue to decline until 1996 (Figure 11). Following this there will be a slow rise back to the 1983 level by the year 2008. During 1996-1998, the trough of the decline, the number of 22-year-olds will be about 25% less than in 1982.

The coming decrease is looked upon with some concern by educators. There is cause for concern about the number of new NS&E's produced annually because of the strength of past linkages between 22-year-olds and NS&E baccalaureates. Recall that this population decline will not be uniform across the Nation, and further, that all institutions that offer college degrees will not feel the impact of the decrease in the same fashion. In addition to the quality of the institution's students, its size and location are also factors that can be expected to make a difference in terms of ultimate impact. These factors are examined in the next several sections.

Population projections of the number of 22-year-olds in 1998 in the East, Midwest, West, and South indicate that the East will have lost 43%, the Midwest 35%, and the South 18%, while the West will have gained 2% [See Figure 8]. At present there are 393 NS&E B.S. granting institutions in the East, 370 in the Midwest, 281 in the West, and 332 in the South. The severest population impacts are expected to be in the areas with the largest number of institutions and with the largest decline in the number of 22-year-olds. These should be greater for public than private institutions, because public institutions depend more on local students.

NUMBER OF U.S. 22-YR-OLDS

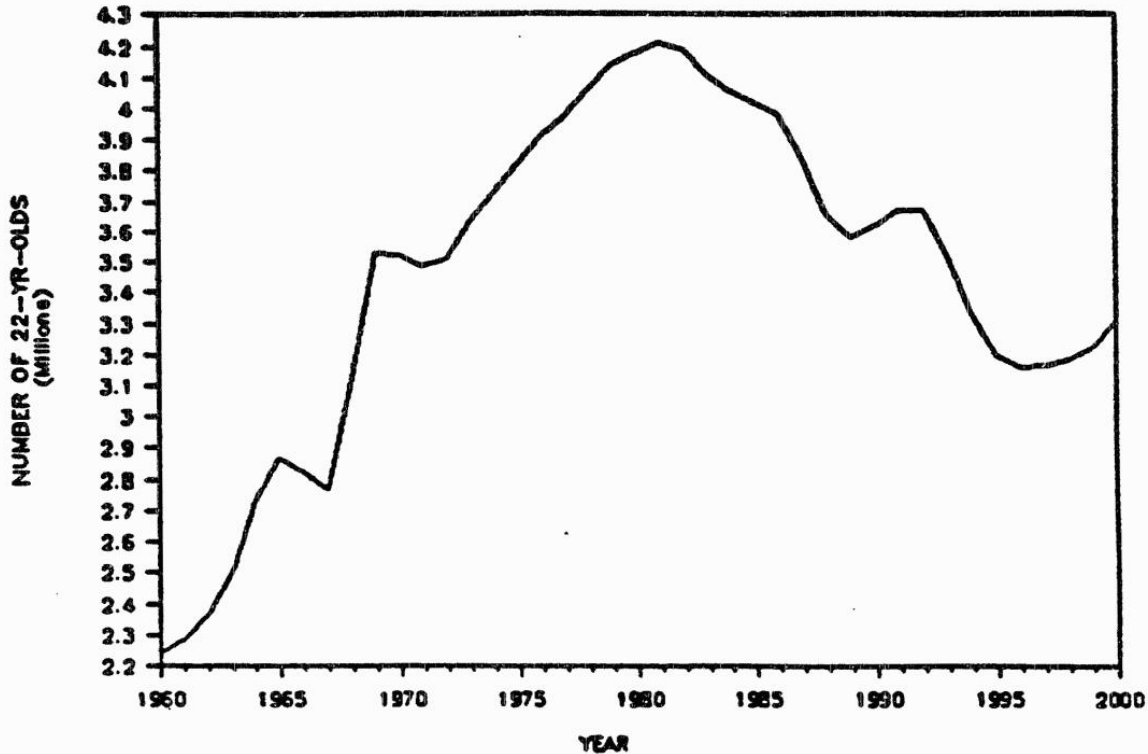


Figure 11

The most significant impact of this decrease from the perspective of those concerned with the health of our science community is that there will be a smaller student body from which to draw new NS&E students. Although it is impossible to make definite (population-based) projections of the supply of NS&E baccalaureates, it is possible to describe what would have to happen in order to maintain the annual flow at the same level experienced in some previous year, e.g., 1983. In 1984, the rate of B.S. degrees in NS&E per 1000 22-year-olds was 51, the highest since 1960, but it would have to climb to 64 per 1,000 by 1996 to maintain a constant annual supply at the 1983 level-- which seems unlikely (Figure 12).

If baccalaureate degree production in NS&E continues at the same rate as prevailed in 1983, then there would be a cumulative reduction of 692,000 B.S. degrees in NS&E during 1985-2010 (Figure 13), compared to the production of degrees that would occur if the population of 22-year-olds and the rate remained at their 1983 levels. The engineering share of this cumulative reduction would be about 256,000 baccalaureates, 17,000 in the worst year (1996).

NS/E BS PARTICIPATION RATE NEEDED TO MEET 1983 OUTPUT LEVEL THROUGH 2012

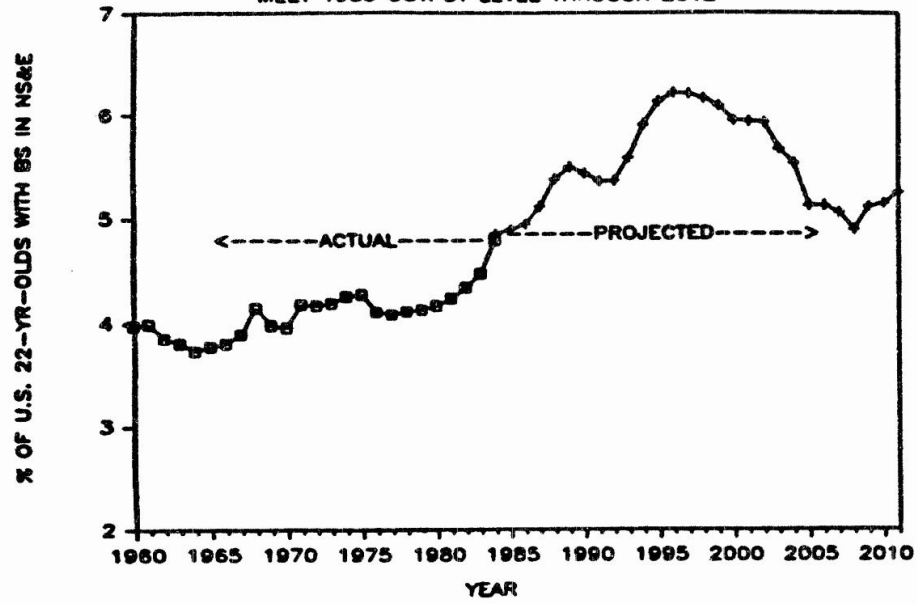


Figure 12

NS&E B.S. PRODUCTION RATES WITH 1983 PARTICIPATION RATE (.048)

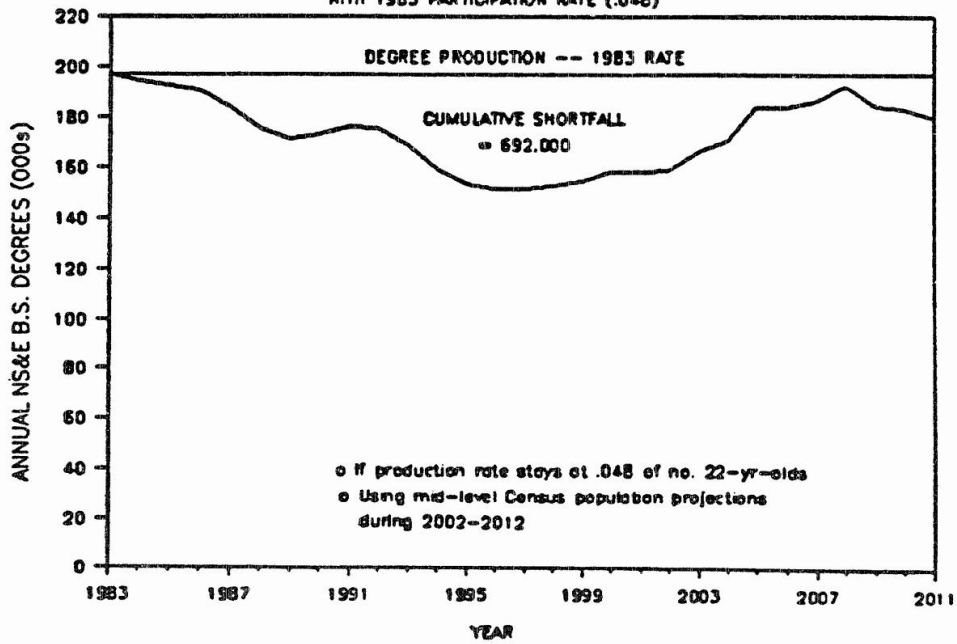


Figure 13

The Ph.D. Labor Market

After 1990, there may be a corresponding population-induced decline in the production of high-quality Ph.D.'s with U.S. citizenship (Figure 14). The impact of an almost certain declining NS&E student population over the next ten years (hence, reduced teaching positions) will exacerbate this decline in domestic doctorates because weak labor markets discourage domestic graduate students from starting or finishing Ph.D. programs. Another long-term issue set off in the Sixties, the so-called "Aging Faculty" problem, will reinforce the reduced demand in the academic market for new Ph.D.'s until the late 1990's. Responding to rapidly growing enrollment, universities and colleges hired large numbers of new faculty during the 1960's--and gave most of them tenure. As a consequence, the need to replace existing faculty that depart or retire from academe has fallen after the early 1970's, and will remain low until the mid-1990's.

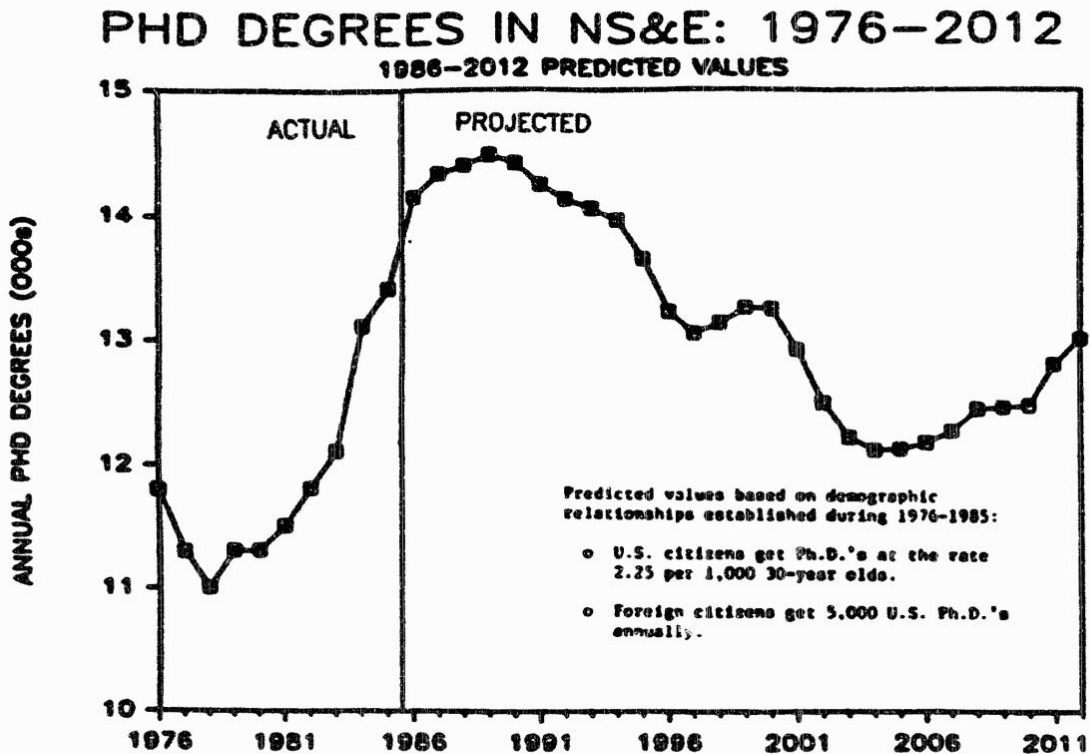


Figure 14

In the late 1990's, the demand for new NS&E Ph.D. teachers will rise rapidly in response to the growing aging faculty retirements and increasing numbers of NS&E students (Figure 15). What is most worrisome is the fact that this surge will have to be stocked from a pool of new Ph.D.'s who are in the pipeline over the next 10 years and trying to make career decisions in the face of a soft academic market.

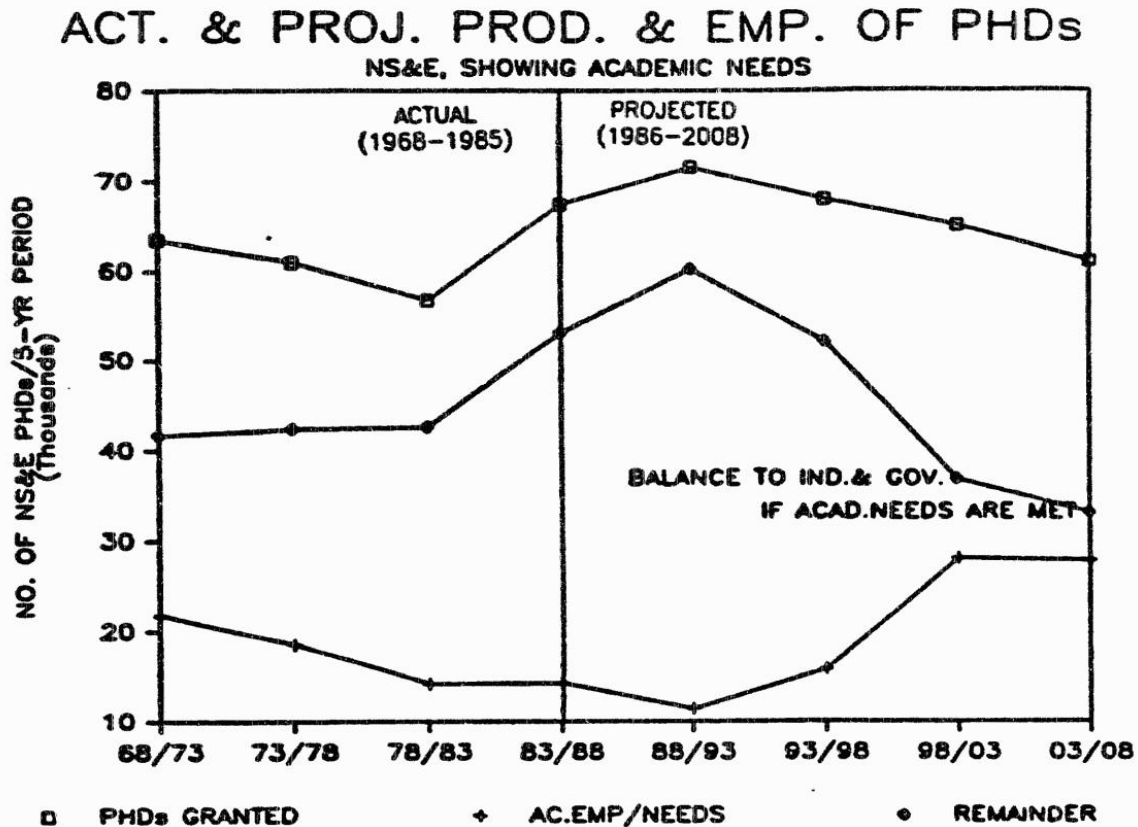


Figure 15

THE POTENTIAL IMPACT

These future supply and demand conditions for scientists and engineers present several potential problems to the academic community and the Nation. Possibly the most serious of these is to be found in the academic community as it tries to recruit researchers and teachers in the decades ahead.

The Seed Corn Dilemma

The anticipated need to replace a large number of our teaching and research faculty around the turn of the Century, and the expectation that the demand for scientists and engineers from the other sectors of the economy will not diminish and will probably increase during this same time period raises the possibility that the academic sector will experience the brunt of any shortage of new NS&E doctorates.

This has been called a seed corn problem because it is the scientists and engineers in the academic community who not only are responsible for the largest portion of our fundamental research but who also train the next generation. This sector's need for a large number of the new Ph.D.'s will remain unfulfilled unless they bid them away from industry and government. Ph.D. salaries in academia have typically been lower than elsewhere and

academe may be poorly positioned financially in the late 1990's to engage in a bidding war. In short, the intellectual capital of the Nation is in danger of being bid away, with the minimum impact being that the people who fill the teaching and research ranks in the universities will be of lower quality. Worse, there may not be enough to even fill the openings.

Careful consideration of the distribution of the decline in NS&E enrollments (and the distribution of the subsequent increase) indicates that the top 100 research universities and top 100 4-year colleges will probably avoid declines. These 200 institutions accounted for about 50% of the NS&E baccalaureates in 1983 and may account for as much as 65% in 1996 if the conferral rate among males remains in the range from 6% to 7% of male 22-year-olds, as expected. The remaining 1,200 institutions producing the remaining 50% of NS&E baccalaureates in 1983 are expected to absorb most of the anticipated decline (Figure 16). This decline could reach 50% in these 1200 institutions if the conferral rate among females remains around 3%, where it is today. On the other hand, an increase in the percentage of female 22-year-olds getting NS&E baccalaureates would reduce the size of this decline. In any case, the surge in NS&E enrollments expected to begin 10 years or so from now should occur primarily within these 1200 "second tier" institutions.

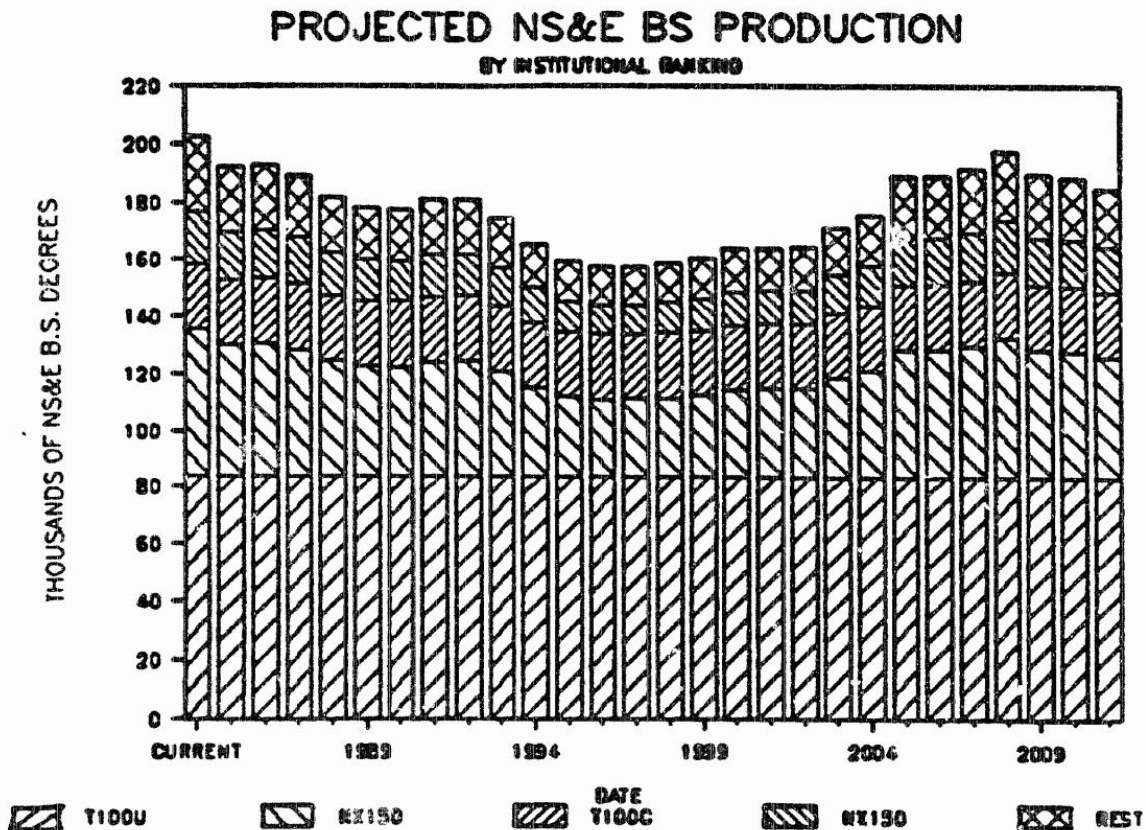


Figure 16

If the decline is experienced primarily in institutions other than the top ranked colleges and universities, then the impacts might be modest from some perspectives, for example, the NS&E research community. Over 90% of NSF funded research in 1983 was conducted by the top 100 research universities. These same 100 institutions produced nearly 80% of the NS&E Ph.D.'s in that year. The top 100 colleges and the top 100 research universities accounted for about 60% of the baccalaureates in NS&E fields which acquired Ph.D.'s in NS&E fields during 1981-84. These same 200 institutions, however, do not account for a significantly higher percentage of the successful Ph.D. candidates in the top 20 graduate programs.

However, in the broader context of the Nation as a whole, there may be adverse effects from inadequate supplies of new NS&E's, and it will probably be important to encourage degree students at all institutions. In our market economy, a growing demand for NS&E degree-holders will have to depend on utilizing workers who are not presently employed in NS&E jobs but have had NS&E training in the past, or it will have to make greater use of technicians. In either case, one can anticipate that an expanding labor force of NS&E's will contain greater numbers of lower quality employees in the sense of less training and experience.

The Problem of Second Tier Institutions

These institutions, that are neither major beneficiaries nor performers of Federally sponsored research, nor (individually) principal producers of B.S. degrees who later become Ph.D.'s still provide one-half of the baccalaureates in NS&E, and 40% of the baccalaureates that become doctorates. As these institutions bear the brunt of the decline in the college-age population, and lose their share and level of production of NS&E baccalaureates, it is possible that policymakers might attempt to provide assistance to their NS&E programs because natural science and engineering programs tend to be more costly to run than programs in the humanities and social sciences. For this reason, it may be worth considering the major types of assistance programs considered or tried in the past. Between 1950 and 1982, roughly \$600 million was spent by NSF on 22 different undergraduate education programs and \$900 million on 20 precollege education programs. An additional \$100 million was spent on eight science programs involving undergraduates and precollege science education.

From NSF's inception in 1950 until 1958, NSF officials seriously considered implementing a scholarship program for undergraduate science education. The launching of Sputnik in October 1957 brought the issue to a head; at that time it was decided that NSF would not award scholarships. Instead, during the 1960's NSF attempted to provide talented students opportunities for improved science and mathematics skills. At the undergraduate and precollege level, this was done by increased emphasis on curriculum development, equipment improvement programs for undergraduate institutions, and research and summer institute programs for high school and college teachers to upgrade their competence. Financial emphasis gradually shifted from precollege to undergraduate education during 1953-1982.

NSF's support of undergraduate and precollege science education decreased as a percentage of the NSF budget, from a peak of 40% in 1959 to 33% in 1960 to 6% during 1976-1980, but increased in terms of current dollars until 1968, reaching almost \$90 million. During 1971-1980, annual support was \$40-60 million. In 1982, as part of overall Federal budget constraints and changing priorities, undergraduate and precollege programs were temporarily phased out, pending new program designs.

These programs had only limited success. For example, the precollege curriculum development programs had a favorable effect on the interest of capable students in science, and their products are still in evidence in today's science textbooks. They did little, however, to broaden the NS&E pipeline at this stage. Newly designed versions of the precollege and undergraduate programs were established in FY 1984, and have grown to 6.1% of the proposed FY 1988 NSF budget of \$1.9 billion. Most of the funding targeted for undergraduate institutions is for upgrading instrumentation, and increasing research and teaching capacity. Emphasis on precollege education is on teaching materials and teaching competence in primary and secondary education.

In spite of these NSF efforts, current levels of funding for undergraduate institutions are unlikely to have a major impact on the fiscal health of second-tier institutions.

POSSIBLE OPTIONS

Labor markets already treat scientists and engineers preferentially in the sense that NS&E degree-holders command relatively high entry-level salaries and they have experienced unemployment at only one-half the rate experienced by the general work force. These advantages have prevailed since the 1950's.

There are a number of responses available to decisionmakers in the public and private sectors to adjust to a shrinking supply of new degree-holders. To help define these potential responses, a simple stock-flow diagram might be visualized (Figure 17). In general, the stock of people in NS&E positions can be increased by increasing the flow of new graduates, reentrants, and immigrants, or by decreasing the rate of attrition of people in NS&E occupations. Attrition may have occurred either voluntarily (career shifts, career advancement) or involuntarily (unemployment, forced retirement, career pressure). Each of these inflows and outflows represents a possible leverage point for use by public policymakers or private employers to ease shortages.

Scientists and Engineers

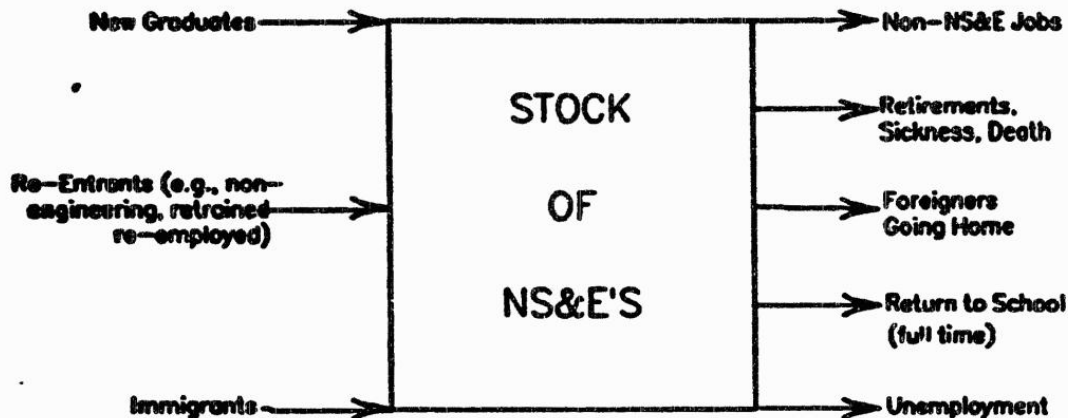


Figure 17

Private Response Strategies

The essential nature of private market response strategies is that the market will automatically adjust the supply with demand for the services of NS&E's.

One issue is the speed of this adjustment, which may take years. Another issue is scarcity, i.e., whether automatic adjustment will provide adequate numbers of NS&E's for the Nation. Some examples of private strategies that might be implemented to reduce the scarcity of NS&E's are: (a) recruitment: recruiting foreign professionals, increasing entry-level salaries to encourage college students to major in NS&E fields with the greatest scarcities, recruiting more students from a given population cohort, and reducing barriers and providing more incentives for women and minorities to select NS&E careers; (b) changes within work force: increasing the responsibility of lower skilled or trained employees, retraining some employees for NS&E jobs (occupation switching), keeping NS&E employees in NS&E occupations for longer periods by altering career path incentives, and providing incentives for delayed retirement of NS&E employees; and (c) substitution of equipment for labor.

All of these private responses have certain costs associated with them and they may reduce the average quality of services provided by employed NS&E's.

Public Sector Options

If the Nation desires that more NS&E's be produced, it must pay for them. Public policy programs can be envisioned as having two major approaches. One is to attract able students to NS&E careers by "subsidizing" those careers through provision of a growing pool of Federal R&D funds awarded to researchers on the basis of merit. Another is to subsidize the costs of acquiring an NS&E education. In the late 1950's, NSF's relatively small budget was nearly evenly split between these two approaches. However, the baby boom cornucopia of new NS&E's led to a shift in emphasis to funding research and supporting doctoral students and post doctoral natural scientists. This approach clearly favors advanced degree-holders over baccalaureates and new NS&E's over future NS&E's. Any policy shift must consider the futility of encouraging more NS&E students and graduates if their employment prospects within their fields are poor. However, if a shortage develops in the future, a shift towards subsidizing the costs of education may prove more cost-effective in encouraging more college students to select careers in NS&E occupations. Three simple public options for subsidizing this cost of acquiring NS&E baccalaureates are: undergraduate scholarships for students majoring in NS&E fields, low-interest loans to these same types of students, and forgivable loans (on acceptance of NS&E employment).

A major problem with making these options generally available to all students is the opportunity cost of rewarding students that would have selected an NS&E major without the incentive. As a result, the costs of untargeted programs are apt to be substantial. Under different assumptions, cumulative 25-year costs range from \$49 billion for a comprehensive scholarship program for all NS&E students, to 40% of that amount for a subsidized loan program.

Targeted programs focused on subgroups of college-age students with below-average baccalaureate attainment rates in NS&E fields are less costly as a consequence of the smaller target and the lower average opportunity cost within the target group. Our estimates of the costs of targeted programs range from \$24 billion (scholarships for women) to \$2.5 billion (subsidized loans to blacks and Hispanics) (Figure 18). If the Federal Government provided 4-year scholarships only to underrepresented Minorities demonstrating at least a minimum of fundamental skills in science or engineering, the cost would be about \$250 million per year (\$6.3 billion over 25 years).

If NS&E's become sufficiently scarce, it is unlikely that policy makers would remain aloof, relying completely on private strategies. One obvious candidate is greater use of foreign NS&E's. Foreign participation in U.S. NS&E labor markets could be encouraged at little direct cost to the Federal Government by relaxation of immigration rules for trained NS&E's who want to work or study in the U.S. Direct immigration of trained NS&E's into U.S. job vacancies is obviously cost effective. Since 1975, from 3% to 6% of new degree-holders in the U.S. labor market were trained abroad. If one half of an expanded flow of immigrant students in NS&E fields were to remain on the U.S. after finishing their education, student immigration could also be considered a cost-effective means of expanding the flow of NS&E's, because it is estimated that slightly less than one-half the cost of educating foreign students in NS&E fields is paid by U.S. sources, primarily state governments.

**Costs and Effectiveness of
Public Sector Options for Undergraduate NS&E's
(\$2,000 per year, 25 years)**

Scope	Cost	Shortfall Reduction
All students	\$49 billion	100%
Women Only	24	100%
Minorities	6.3	50%
Blacks	3.6	26%
Hispanics	2.7	24%

- o Subsidized loan program would be about 40% of full scholarship. (5%, 10-year, evidence of need)
- o Forgivable loan program would be about 60% of full scholarship cost (S&E's employed by F, S, L govt. or schools)

Figure 18

The quality of foreign NS&E's has, so far, been at least on a par with U.S. citizen NS&E's. In graduate engineering programs, where the number of foreign students currently exceed U.S. students, and where significant percentages of students have been foreigners on temporary visas for more than a decade, quality has never been a widespread problem. Graduate foreign students in NS&E fields are distributed across institutions ranked by quality in approximately the same proportions as other graduate students.

The major remaining issues surrounding the growing importance of foreign students are language and culture. It is possible in NS&E fields for students to enter and graduate with weak English language skills, despite nominal proficiency requirements. If these students or graduates occupy teaching positions in U.S. institutions, it is alleged that the quality of education in those institutions could be impaired. It is possible that stricter standards and policies within individual universities could go a long way in solving this problem. For example, influential faculty, flush with grant money, may funnel off the best domestic students as research assistants, leaving too few available for teaching assistance. Internal policies could prevent this practice.

Culture is an issue for female faculty and students that are required to interact with foreign male faculty and students from Nations where females play subordinate roles to males. Again, it is possible that stricter institutional standards and policies would keep this source of conflict under control.

Women and minorities also play a potentially significant role in the shortfall picture. Women provide a large pool of relatively untapped potential for new NS&E degree-holders, particularly in traditionally male fields, such as engineering. In fact, they have begun to comprise an increasing share of the engineering workforce, even though enrollments of women engineering students have declined slightly in 1983. Minorities, specifically Blacks and Hispanics, have also been greatly underrepresented in science and engineering, compared to their fraction of the total population. Worse, Black enrollments have been declining since 1981. In addition to the underrepresentation and the recent downturn, Blacks and Hispanics have the lowest rates of completion in NS&E degree programs. In Engineering fields, this so-called persistence rate is only 29% as compared to the national total of 79%.

All "teaching" programs have some merit, as well as problems. On the negative side, they all have quality as well as cost impacts which, under ordinary (past) conditions, would be considered undesirable. But a situation that is defined by a declining supply, rising demand, and a Federal budgetary crisis, might lead to different perceptions of what are acceptable, or qualified, entrants to the NS&E pool of the Nation.

CLOSING STATEMENTS

Attempts by the public sector to produce more natural scientists or engineers must involve strategies that have as their goal getting more of both. For example, the flow of engineering degrees can be increased at the expense of the flow of computer science and physics degrees, but this merely shifts the shortage from engineering to physics and computer science.

In the end, it may become increasingly harder to raise the percentage of 22-year-olds getting NS&E baccalaureates to increasingly higher levels. This means that programs focused exclusively on manpower may prove to be very costly in terms of results. All is not lost, however. There are other things which might be done to augment manpower programs: (1) make more use of computers and other capital equipment, both in the training of NS&E's and in their workplace; (2) institute a program of continuing education or training for the practicing scientist and engineer in addition to making every effort to ensure that their work experience is as relevant as possible; and, finally, (3) when these students graduate and join the workforce, they should be given more and better technicians to work with, as well as other support services, so that they are able to more efficiently and effectively carry out their jobs.

**PERSONNEL IN NATURAL SCIENCE
AND ENGINEERING**

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

WORKING DRAFT

June 1988

The NS&E Pipeline

Several national economic indicators imply a probable continued growth in demand for scientists and engineers for the foreseeable future. At the same time, demographic data indicate a probable decline in the nation's production of college graduates with those skills. This paper presents data which specify the size and nature of supply shortages which are likely to occur in the absence of radical changes in young people's career choices. The paper also presents generic governmental strategies which might attract and retain more students for science and engineering disciplines.

Under the current apprenticeship system of graduate education in natural science and engineering, research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality of research performed cannot be considered separately from concerns about the demand for and supply of researchers. Efforts to address concerns about supply and demand have, in general, relied on judgments. This is because it is not clear how to forecast the production of these scientists and engineers and, more importantly, how many of them will be required to fill future jobs. To some extent, such analyses are driven by the assumptions built into them, with shortages or surpluses looming or vanishing with the adjustment of a number on a computer spreadsheet. The following charts have been constructed with this in mind in the sense that they have made as few assumptions as the data permit, and these assumptions are kept as simple as possible. In the main, the following analyses have made use of trends that have been with us for years; in a few cases, decades. They merely hold that if these trends continue, and if society does nothing to alter them, one can expect the future to grow in a straightforward fashion from the past. Or, if an imbalance exists and the system acts to adjust for it in a standard fashion, absent any intervention, the forecasted results can be expected.

The discussion is focussed principally on natural scientists and engineers (NS&Es), especially Ph.D. NS&Es, rather than the larger population of scientists and engineers which includes the sub-population of social and behavioral scientists. The choice of focus is based on observed differences in patterns of production and demand for NS&Es and for behavioral and social scientists. For the latter, production and demand is less closely linked to the health of the economy and demographic fluctuations than for NS&Es.

Supply

Irrespective of the many factors that enter into the choice of careers, the share of the college age population obtaining B.S. degrees in NS&E has been between 4 and 5 percent for almost three decades (Figure 1). Career intentions data of Freshmen, indicating the percent who have chosen a major in Natural Science and Engineering, suggest that the rate of B.S. degree conferrals to 22-year-olds (the average age at which such conferrals occur) will fall to below 5%. The estimate of 5% used in the projections is optimistic but not unreasonable, so it does not overstate the future supply or downplay the severity of the forecasted shortfalls through 1990. If the 5% share is sustained, the dominant factor controlling the future supply of these scientists and engineers is the size of the pool from which they are drawn (Figure 2). The number of people in the 22-year-old age group has begun to decline and will continue to do so until after the mid-1990s, at which time it will begin to rise again. Projection of freshman intention data indicates that this expected downturn will be evident in the next few years.

Over the past three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly. If one divides the set of NS&E into three major components, natural science, engineering, and computer science, one gets

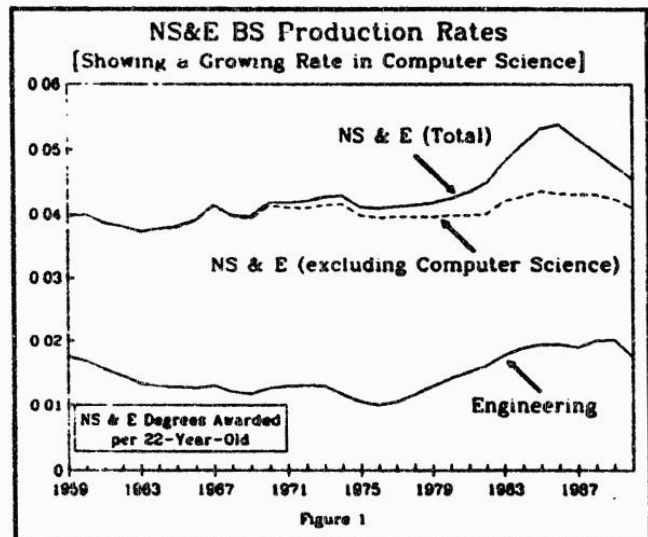


Figure 1

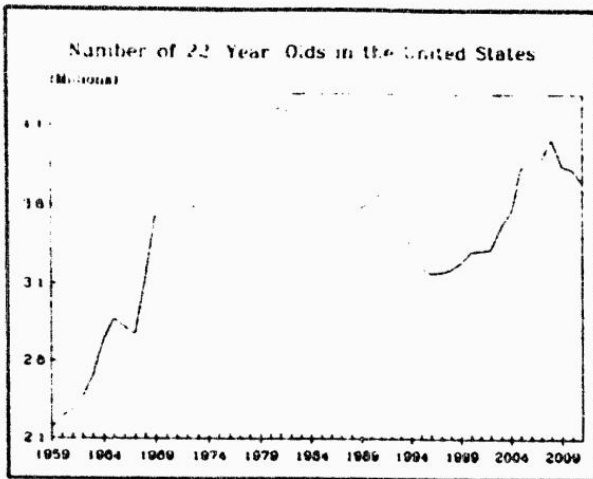


Figure 2

a very different picture of the trend in degree production of disciplinary groups depending on which of the components is being examined. Natural science degrees, for example, peaked in the mid-1970s and have been declining ever since. Engineering degrees, on the other hand, have been increasing over the same period. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the twenty-two year-old population. It is unclear whether this rate will continue into the future as the declared intentions of the current student body presages a significant drop. The addition of computer science degree earners makes this a much less coherent set. In the early 1970s until the early 1980s, the number of individuals receiving computer science degrees was relatively small, likely coming from the same pool as the scientists and engineers. Recent data, and the continuing substantial growth in numbers of these degrees show that they are drawn from several fields,

and there is some evidence that they attract a student body that previously were not candidates for college degrees. The production of these degrees are expected to fall substantially in the near future, so the issue may soon be less significant than at present (Figure 3).

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5 percent of 22-year-olds to 2.5 percent of 22-year-olds in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

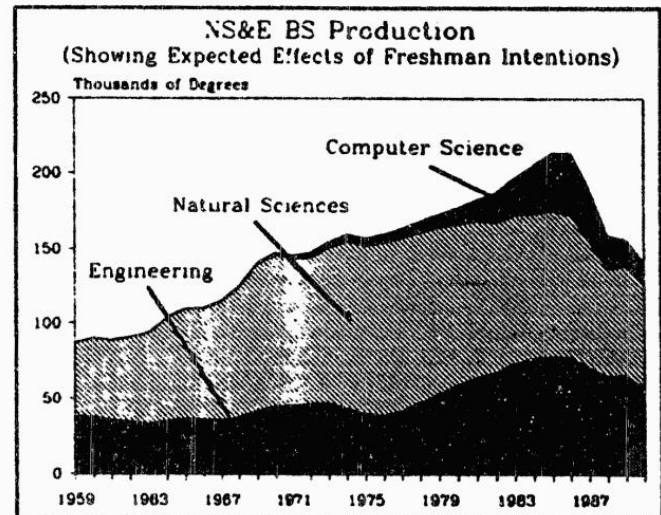


Figure 3

The 5 percent conferral rate is conservative because underrepresented minorities have been (and are expected to continue) growing at a proportion of all 22-year-olds. The participation rate of the underrepresented minorities has been substantially below average during the last ten years. Currently, blacks account for 13 percent of 22-year-olds but only 4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010.

The data suggest that absent some positive action to overcome the observed tendencies in students' choices in courses of study, the number of students in the fields of natural science and engineering will decline. The lowered production rate for these occupations has termed a "shortfall." The size of the shortfall depends on the demand for such skills in the future. This analysis does not attempt to forecast future demands. The shortfall is simply the difference from the 1983 production level. If the

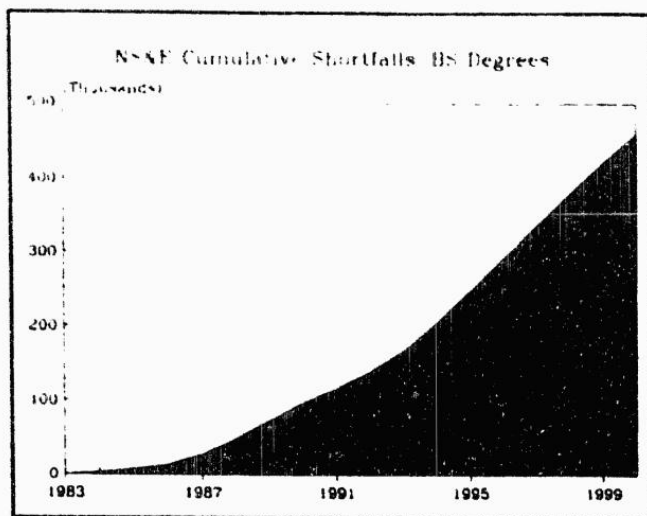


Figure 4

drifted up over the last 5 years to about 31 years old in 1986.

Perhaps the major reason for a weaker population-degree link at the Ph.D. level is the greater importance of specific economic considerations in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. The Ph.D. production in natural science and engineering approximately tripled between 1960 and 1972, dropped gradually in the late Seventies, then slowly recovered, though not quite to its 1972 level. Most of this recovery, particularly recently, is due to a rise in Ph.D.s conferred to foreign citizens who are in the United States on a temporary basis. On the average, across all NS&E fields, the U.S. retains about half of the foreign-born Ph.D. candidates (studying in the U.S. on student visas) as members of the workforce after they finish their doctorates. Unlike its influence on B.S. degrees, Computer Science is not a major factor in the total number of Ph.D. degrees granted in NS&E (Figure 5). Demographic trends will affect future supplies of Ph.D.s, which are dependent on baccalaureate production as noted earlier in the context of the "pipeline" discussion. Most obviously, if the rate of conferral remains fixed at 5 percent of U.S. citizens receiving baccalaureates in NS&E and a fixed number of foreign citizens (say 3,500, as a point of discussion), then the number of new S&E Ph.D.s will rise slightly to almost 14,000 in 1989 and 1990, and will subsequently decline steadily into the next century, falling below 12,000 in 1999.

Outside of the traditional NS&E pipeline, immigrants may help to compensate for the drop in Ph.D. production brought about by demographic changes in the U.S. population. In the last several decades, Ph.D.s trained in foreign countries have not been a significant source of NS&E personnel. Since 1975, from 3 to 6 percent of new degree-holders in the U.S. labor market were trained abroad. On the other hand, foreign doctoral students (on temporary visas) studying in U.S. universities have been a significant source of supply in NS&E fields, assuming many of them remained in the U.S. to work after finishing their studies. These foreign students accounted for more than 25 percent of NS&E Ph.D.s in 1986.

NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the turn of the century would be about 430,000, with 160,000 being in engineering degrees (Figure 4).

Ph.D. Shortages

It has been assumed that the shortage of baccalaureate degrees also means a corresponding shortage of doctorates. The historical link between population and degree production has not been as strong at the Ph.D. level, in contrast to the 4 percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new S&E Ph.D.s was 30 years old during the 1960s and 1970s, but this has

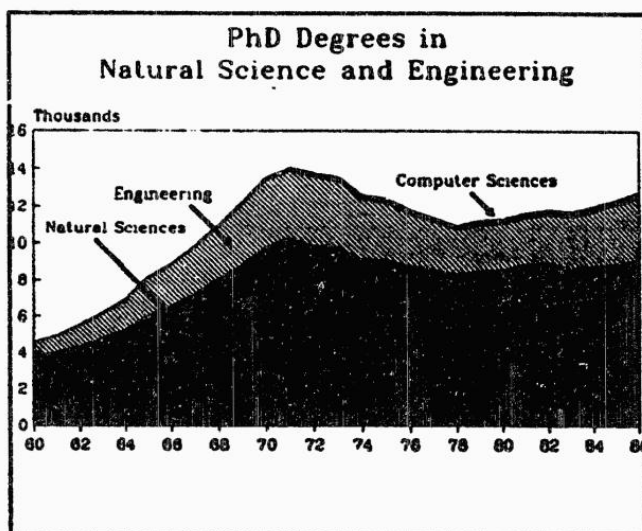


Figure 5

**PERSONNEL IN NATURAL SCIENCE
AND ENGINEERING**

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

WORKING DRAFT

June 9, 1998

The NS&E Pipeline

A fundamental feature of the way research is carried out in the United States is the joint production of research and education for the next generation of scientists and engineers. Although there has been some argument, at times, that there may be equally effective ways to accomplish the desired research there has never been a serious challenge to the orthodoxy of the apprenticeship method of training graduate students as the best way to educate advanced degree students.

Consequently, in addition to being concerned about the amount and quality of the research itself, the production of the next generation of researchers is very important too. In general, efforts to address this concern have relied on judgements. This is because it is not clear how to forecast the production of these scientists and engineers and, more importantly, how many of them will be required to fill future jobs. To some extent, such analyses are driven by the assumptions built into them, with shortages or surpluses looming or vanishing with the adjustment of a number on a computer spreadsheet. The following charts have been constructed with this in mind in the sense that they have made as few assumptions as the data permit, and these assumptions are kept as simple as possible. In the main, the following analyses have made use of trends that have been with us for years; in a few cases, decades. They merely hold that if these trends continue, and if society does nothing to alter them, one can expect the future to grow in a straightforward fashion from the past. Or, if an imbalance exists and the system acts to adjust for it in a standard fashion, absent any intervention, the forecasted results can be expected.

The following discussion is focussed principally on issues concerning production of, and demand for, natural scientists and engineers (NS&Es), especially Ph.D. NS&Es, rather than the larger population of scientists and engineers which includes the sub-population of social and behavioral scientists. The choice of focus is based on observed differences in patterns of production and demand for NS&Es and for behavioral and social scientists. For the latter, production and demand is less closely linked to the health of the economy and demographic fluctuations than for NS&Es.

Supply

The factors that cause a young person to chose a career in science or engineering are not known. But, whatever they are, the share of that age cohort of college population which typically obtain B.S. degrees in NS&E has been pretty constant at about 4.5 percent for almost three decades (Figure 1). Career intentions data of Freshmen to examine the percent who have chosen a major in Natural Science and Engineering, suggest that the rate of B.S. degree conferrals to 22-year-olds (the average age at which such conferrals occur) will fall to below 5%. Consequently, the estimate of 5% we have used in our analyses is felt to be generous but not unreasonable, as it would overstate the future supply and downplay the severity of the forecasted shortfalls.

If the 5% share is sustained, the most telling characteristic of future supply of these scientists and engineers is certain to be the size of the pool from which they are drawn (Figure 2). Starting a couple of years ago the number of people in the 22-year-old age group began to decline and will continue to do so until after the mid-1990s, at which time it will begin to rise again. Our forecast of the expected number of degrees in these fields shows that this expected downturn has begun.

Over the past two, almost three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly. If one divides the set of NS&E into three major components, natural science, engineering, and computer science, one gets a very different picture of the trend in degree production

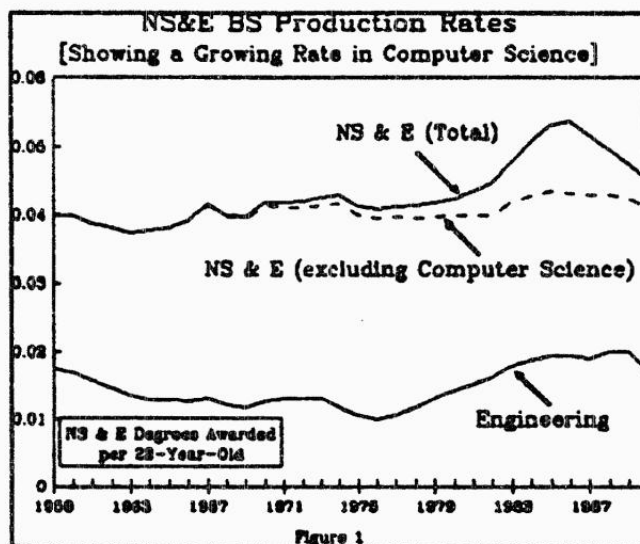


Figure 1

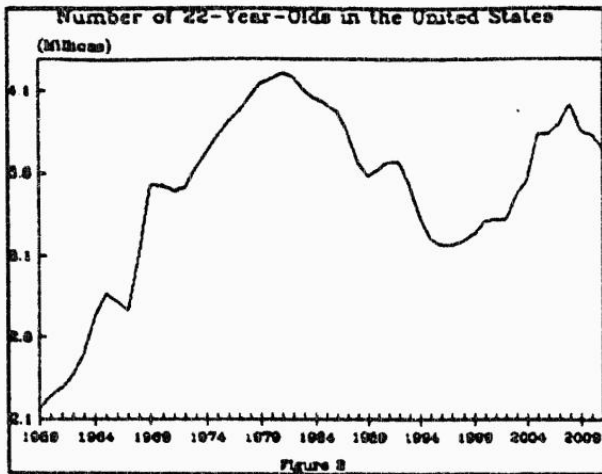


Figure 2

individuals receiving computer science degrees was relatively small and one could argue that their numbers were drawn from the same pool as the scientists and engineers. Recent data, and the continuing substantial growth in numbers of these degrees show that they are drawn from several fields -- and indeed, there is some evidence that they attract a student body that previously were not candidates for college degrees. On the other hand, the production of these degrees are expected to fall substantially in the near future, so the issue may soon be less significant than at present (Figure 3).

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5 percent of 22-year-olds to 2.5 percent of 22-year-olds in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

of disciplinary groups depending on which of the components is being examined. Natural science degrees, for example, peaked in the mid-1970s and have been declining ever since. Engineering degrees, on the other hand, have been increasing over the same period. The two of them, if combined, show a considerably modulated growth which, when normalized as a proportion of the entire baccalaureate pool, turns out to be about 4.5% of the total. It is unclear whether this rate will continue into the future as the declared intentions of the current student body presages a significant drop. The addition of computer science degree earners makes this a much less coherent set. Whereas there seems to be some natural migration between those who might choose to be scientists or engineers in the sense that the data shows a complementarity between the two, there is no such relationship apparent with the field of computer science. In the early Seventies and until the early Eighties, the number of

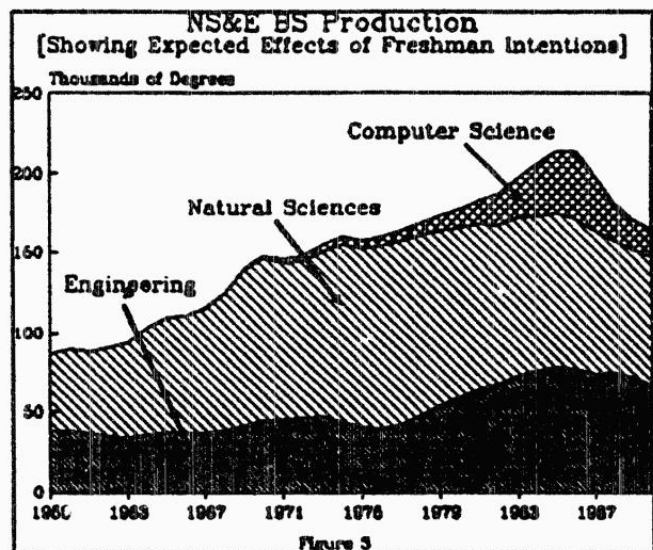


Figure 3

The data suggest absent some positive action to overcome the observed tendencies in students' choices in courses of study, the number of students in the fields of natural science and engineering are sure to decrease. We have identified this as a shortfall. The size of the shortfall is arguable; the significant question is "compared to what?" For purposes of this analysis we have sidestepped the issue by simply describing the shortfall as a deviation from the 1983 level. If one took the persistence rates of those students who tended to get degrees in natural science and engineering into consideration with

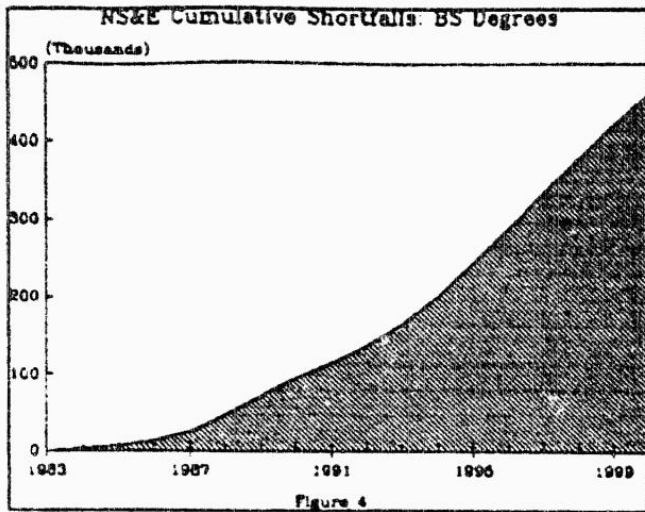


Figure 4

drifted up over the last 5 years to about 31 years old in 1986.

Perhaps the major reason for a weaker population-degree link at the Ph.D. level is the greater importance of specific economic considerations in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. The Ph.D. production in natural science and engineering approximately tripled between 1960 and 1972, dropped gradually in the late Seventies, then slowly recovered, though not quite to its 1972 level. Most of this recovery, particularly recently, is due to a rise in Ph.D.s conferred to foreign citizens who are in the United States on a temporary basis. On the average, across all NS&E fields, the U.S. retains about half of the foreign-born Ph.D. candidates (studying in the U.S. on student visas) as members of the workforce after they finish their doctorates. Unlike its influence on B.S. degrees, Computer Science is not a major factor in the total number of Ph.D. degrees granted in NS&E (Figure 5). Demographic trends will affect future supplies of Ph.D.s, which are dependent on baccalaureate production as noted earlier in the context of the "pipeline" discussion. Most obviously, if the rate of conferral remains fixed at 5 percent of U.S. citizens receiving baccalaureates in S&E and a fixed number of foreign citizens (say 5,000, as a point of discussion), then the number of new S&E Ph.D.s will rise slightly to almost 20,000 in 1989 and 1990, and will subsequently decline steadily into the next century, falling below 16,000 in 1999.

Outside of the traditional NS&E pipeline, immigrants may help to compensate for the drop in Ph.D. production brought about by demographic changes in the U.S. population. In the last several decades, Ph.D.s trained in foreign countries have not been a significant source of NS&E personnel. Since 1975, from 3 to 6 percent of new degree-holders in the U.S. labor market were trained abroad. On the other hand, foreign doctoral students (on temporary visas) studying in U.S. universities have been a significant source of supply in NS&E fields, assuming many of them remained in the U.S. to work after finishing their studies. These foreign students accounted for more than 25 percent of NS&E Ph.D.s in 1986.

The demand for scientists and engineers can be ascertained by assuming the replacement plus any new requirements for the various sectors of the economy. Figure 6 shows such demands for academia,

the fate of the cohort of 22-year-olds, the cumulative shortfall of B.S. degrees to the turn of the century would be about 430,000, with 160,000 being in engineering degrees (Figure 4).

Ph.D. Shortages

It has been assumed that the shortage of baccalaureate degrees also means a corresponding shortage of doctorates. The historical link between population and degree production has not been as strong at the Ph.D. level, in contrast to the 4 percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new S&E Ph.D.s was 30 years old during the 1960s and 1970s, but this has

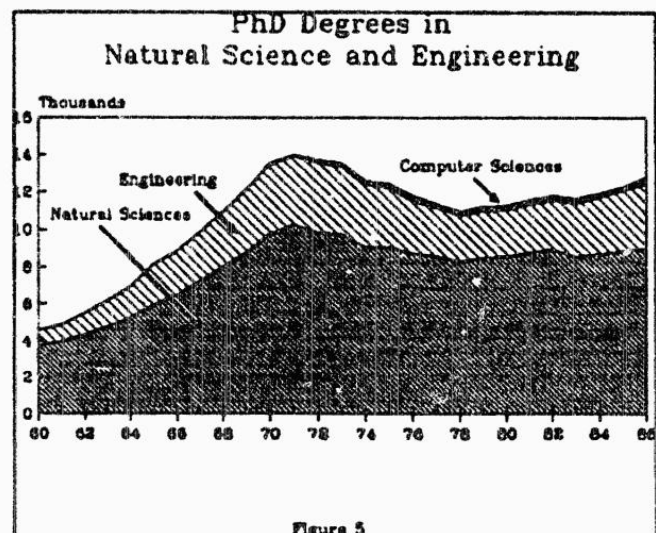


Figure 5

**PERSONNEL IN NATURAL SCIENCE
AND ENGINEERING**

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

WORKING DRAFT

October 1988

The NS&E Pipeline

Several national economic indicators imply a probable continued growth in demand for scientists and engineers for the foreseeable future. At the same time, demographic data indicate a probable decline in the nation's production of college graduates with those skills. This paper presents data which specify the size and nature of supply shortages which are likely to occur in the absence of radical changes in young people's career choices. The paper also presents generic governmental strategies which might attract and retain more students for science and engineering disciplines.

Objective is to describe potential supply shortage of scientists and engineers.

Under the current apprenticeship system of graduate education in natural science and engineering, research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality

Analysis based on examination of trends over 25 years for natural scientists and engineers (SE&E).

of research performed cannot be considered separately from concerns about the demand for and supply of researchers. Efforts to address concerns about supply and demand have, in general, relied on judgments. This is because it is not clear how to forecast the production of these scientists and engineers and, more importantly, how many of them will be required to fill future jobs. To some extent, such analyses are driven by the assumptions built into them, with

shortages or surpluses looming or vanishing with the adjustment of a number on a computer spreadsheet. The following charts have been constructed with this in mind in the sense that they have made as few assumptions as the data permit, and these assumptions are kept as simple as possible. In the main, the following analyses have made use of trends that have been with us for years; in a few cases, decades. They merely hold that if these trends continue, and if society does nothing to alter them, one can expect the future to grow in a straightforward fashion from the past. Or, if an imbalance exists and the system acts to adjust for it in a standard fashion, absent any intervention, the forecasted results can be expected.

Long-term data suggest an upper limit of 5 percent of college age population receiving NS&E BS degrees.

The discussion is focussed principally on natural scientists and engineers (NS&Es), especially Ph.D. NS&Es, rather than the larger population of scientists and engineers which includes the sub-population of social and behavioral scientists. The choice of focus is based on observed differences in patterns of production and demand for NS&Es and for behavioral and social scientists. For the latter, production and demand is less closely linked to the health of the economy and demographic fluctuations than for NS&Es.

Dominant factor controlling NS&E supply is size of college population pool, which will decline until late 1990's.

Supply

Irrespective of the many factors that enter into the choice of careers, the share of the college age population obtaining B.S. degrees in NS&E has been between 4 and 5 percent for almost three decades (Figure 1). Career intentions data of Freshmen, indicating the percent who have chosen a major in Natural Science and Engineering, suggest that the rate of B.S. degree conferrals to 22-year-olds (the average age at which such conferrals occur) will fall to below 5%. The estimate of 5% used in the

projections is optimistic but not unreasonable, so it does not overstate the future supply or downplay the severity of the forecasted shortfalls through 1990. If the 5% share is sustained, the dominant factor controlling the future supply of these scientists and engineers is the size of the pool from which they are drawn (Figure 2). The number of people in the 22-year-old age group has begun to decline and will continue to do so until after the mid-1990s, at which time it will begin to rise again. Projection of freshman intention data indicates that this expected downturn will be evident in the next few years.

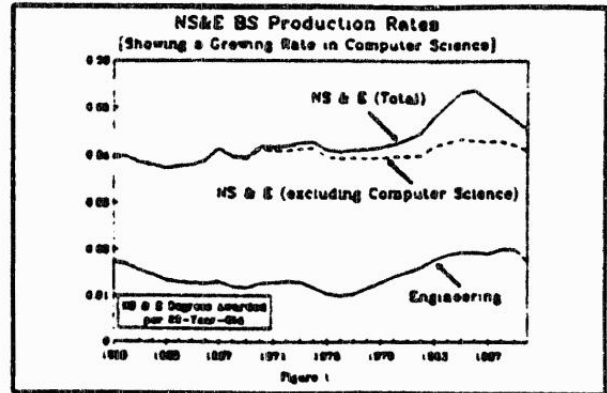


Figure 1

Most growth of computer science baccalaureates did not come from likely candidates for baccalaureates in other NS&E disciplines.

Over the past three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly.

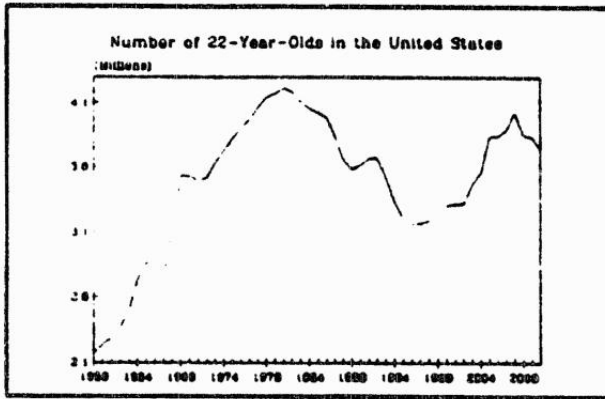


Figure 2

same pool as the scientists and engineers. Recent data of these degrees show that they are drawn from several fields, and there is some evidence that they attract a student body that previously were not candidates for college degrees. The production of these degrees are expected to fall substantially in the near future, so the issue may soon be less significant than at present (Figure 3).

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5

If one divides the set of NS&E into three major components, physical sciences, life sciences, and biological sciences, one gets a very different picture of the trend in degree production of disciplinary groups depending on which of the components is being examined. Natural science degrees, for example, peaked in the mid-1970s and have been declining ever since. Engineering degrees, on the other hand, have been increasing over the same period. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the twenty-two year-old population. It is unclear whether this rate will continue into the future as the declared intentions of the current student body presages a significant drop. The addition of computer science degree earners makes this a much less coherent set. In the early 1970s until the early 1980s, the number of individuals receiving computer science degrees was relatively small, likely coming from the data, and the continuing substantial growth in numbers

Slow persistent growth in rate of conferral of NS&E baccalaureates to women offset by a decline in conferral to men.

percent of 22-year-olds to 2.5 percent of 22-year-olds in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

The 5 percent conferral rate is conservative because underrepresented minorities have been (and are expected to continue) growing at a proportion of all 22-year-olds. The participation rate of the underrepresented minorities has been substantially below average during the last ten years. Currently, blacks account for 13 percent of 22-year-olds but only

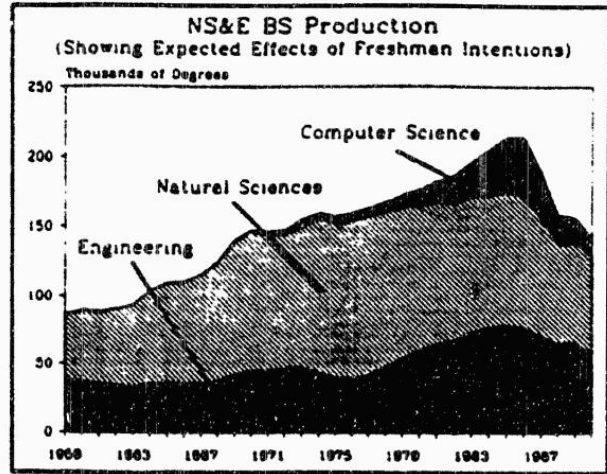


Figure 3

4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010.

By 2000 the U.S. will have a 730,000 short fall of NS&E's.

The data suggest that absent some positive action to overcome the observed tendencies in students' choices in courses of study, the number of students in the fields of natural science and engineering will decline. The cumulative lowered production for these occupations has been termed a shortfall. The size of the problem caused by the lowered production depends on the need for such skills in the future in a preferred configuration of the economy. This analysis does not attempt to forecast future demands. The shortfall is simply the difference between the number of projected NS&E baccalaureates and the number which would exist from maintaining the 1983 production level. If the NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the turn of the century would be about 430,000, with 160,000 being in engineering degrees (Figure 4).

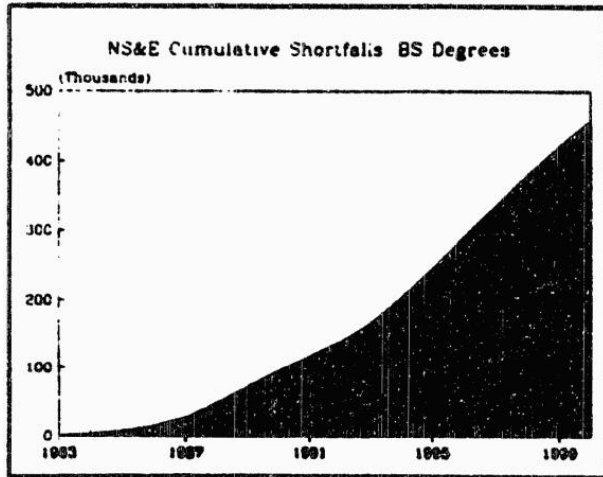


Figure 4

Ph.D. Shortages

It has been assumed that the shortage of baccalaureate degrees also means a corresponding shortage of doctorates. The historical link between population and degree production has not been as strong at the Ph.D. level, in contrast to the 4 percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new S&E

Ph.D.s was 30 years old during the 1960s and 1970s, but this has drifted up over the last 5 years to about 31 years old in 1986.

Two major reasons for a weaker population-degree link to the Ph.D. degree production are the greater importance of specific economic considerations and immigrations in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. The Ph.D. production in

**PRIVATE AND PUBLIC RESPONSES TO
PERSONNEL SHORTAGES IN NATURAL
SCIENCE AND ENGINEERING**

DRAFT

***Options for Augmenting the Supply of
Natural Scientists and Engineers***

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

WORKING DRAFT

February 1989

The NS&E Pipeline

Several national economic indicators imply a probable continued growth in demand for scientists and engineers for the foreseeable future. At the same time, demographic data indicate a probable decline in the nation's production of college graduates with those skills. This paper presents data which specify the size and nature of shortages which are likely to occur in the absence of substantial changes in young people's career choices. The paper also presents generic governmental strategies which might attract and retain more students for science and engineering disciplines. At the Ph.D. level, this paper considers various combinations of additional graduate fellowship programs and equilibrium values of Ph.D.'s hired and Ph.D. salaries.

Objective is to describe potential supply shortage of scientists and engineers.

Under the current apprenticeship system of graduate education in natural science and engineering, research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality of research performed cannot be considered separately from concerns about the demand for and supply of researchers. Efforts to address concerns about supply and demand have, in general, relied on judgments. This is because it is not clear how to forecast the production of these scientists and engineers and, more importantly, how many of them will be required to fill future jobs. To some extent, such analyses are driven by the assumptions or vanishing with the adjustment of a number on been constructed with this in mind in the sense

Analysis based on examination of trends over 25 years for natural scientists and engineers (NS&E).

built into them, with shortages or surpluses looming a computer spreadsheet. The following charts have been constructed with this in mind in the sense that they have made as few assumptions as the data permit, and these assumptions are kept as simple as possible. In the main, the following analyses have made use of trends that have been with us for years; in a few cases, decades. They merely hold that if these trends continue, and if society does nothing to alter them, one can expect the future to grow in a straightforward fashion from the past. Or, if an imbalance exists and the system acts to adjust for it in a standard fashion, absent any intervention, the forecasted results can be expected.

Long-term data suggest the percent of the college age population receiving NS&E BS degrees is unlikely to be much over 5 percent.

The discussion is focussed principally on natural scientists and engineers (NS&Es), especially Ph.D. NS&Es, rather than the larger population of scientists and engineers which includes the sub-population of social and behavioral scientists. The choice of focus is based on observed differences in patterns of production and demand for NS&Es and for behavioral and social scientists. For the latter, production and demand is less closely linked to the health of the economy and demographic fluctuations than for NS&Es.

Supply: B.S. degrees

Dominant factor controlling NS&E B.S. supply is size of college population pool, which will decline until late 1990's.

Irrespective of the many factors that enter into the choice of careers, the share of the college age population obtaining B.S. degrees in NS&E has been between 4 and 5 percent for almost three decades (Figure 1). Freshman career intentions data, indicating the percent who have chosen a major in Natural Science and

Engineering, predict that the rate of B.S. degree conferrals to 22-year-olds (the average age at which such conferrals occur) will fall to below 5% in 1989 and 1990. Five percent is used in the projections in this paper. This is optimistic but not unreasonable. It does not greatly overstate the future supply or downplay the severity of the forecasted shortfalls through 1990. If the 5% rate is unchanged, the factor controlling the future supply of scientists and engineers is the size of the pool from which they are drawn (Figure 2). The number of people in the 22-year-old age group is declining and will continue to do so until after the mid-1990s, at which time it will begin to rise again. Projection of freshman intention data indicates that this field choice will combine with the

demographic downturn, and that a decrease in NS&E B.S. degrees will be evident in the next few years.

Most growth of computer science baccalaureates did not come from likely candidates for baccalaureates in other NS&E disciplines.

Over the past three decades, the number of baccalaureate degrees in natural science and

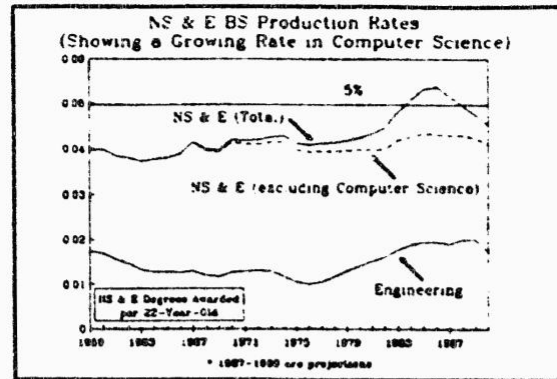


Figure 1

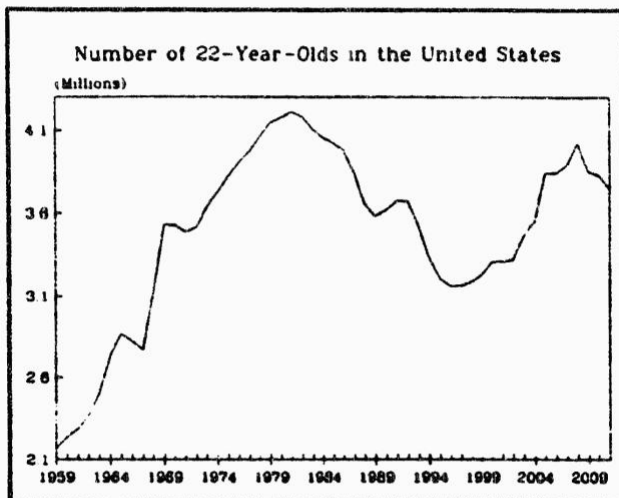


Figure 2

engineering has increased steadily with population, but the growth of the individual components has shifted significantly. Separating NS&E into three major components (natural sciences, computer sciences, and engineering) presents very different pictures of the trend in degree production components. Natural science degrees, for example, peaked in the mid-1970s and have since been declining. Engineering degrees, on the other hand, have been increasing since the mid-1970s. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the twenty-two year-old population. The declared intentions of the current student body presages a significant drop due primarily to demographics. The addition of computer science degree earners makes this a much less coherent set. In the early 1970s until the early 1980s, the

number of individuals receiving computer science degrees was relatively small, likely coming from the same pool as the scientists and engineers. Recent data, and the continuing substantial growth in numbers of these degrees suggest that they have been increasing at the expense of a number of non NS&E fields. There is even some evidence that they attract students that previously were not candidates for B.S. degrees. The intentions data imply that production of computer science degrees will fall substantially in the near future (Figure 3).

Slow persistent growth in the rate of conferral of NS&E baccalaureates to women has been largely offset by a decline in conferrals to men.

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent of female 22-year-olds in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent of male 22-year-olds in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5 percent of female 22-year-olds to 2.5 percent in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of female 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

The 5 percent conferral rate is probably optimistic as a projection because underrepresented minorities have been (and are expected to continue) growing at a proportion of all 22-year-olds. The

participation rate of the underrepresented minorities has been substantially below average during the last ten years. Currently, blacks account for 13 percent of 22-year-olds but only 4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-

By 2006 the U.S. will have a cumulative shortfall of 675,000 NS&E B.S.s.

year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010.

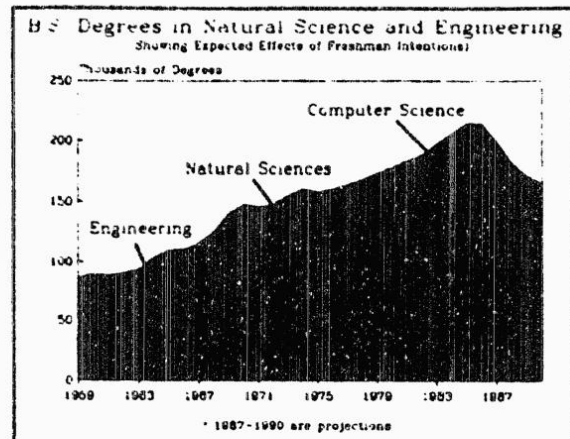


Figure 3

The data suggest that unless some positive action is forthcoming to overcome the observed tendencies in students' choices in courses of study, B.S. degree production in the fields of natural science and engineering will decline. The cumulative reductions in production of these B.S. degrees is what we call a shortfall. This analysis does not attempt to forecast future demands for B.S. degree earners. The size of the problem caused by the lowered production depends on the need for such skills in the future in a healthy competitive economy. The shortfall is measured as the drop in estimated future production from the 1983 production level. If the NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the year 2006 would be about 675,000, with 275,000 being in engineering degrees (Figure 4). Even if we assume that "demand" decreases by 1000 B.S. earners as year, a shortfall of about 440,000 would still occur by 2006.

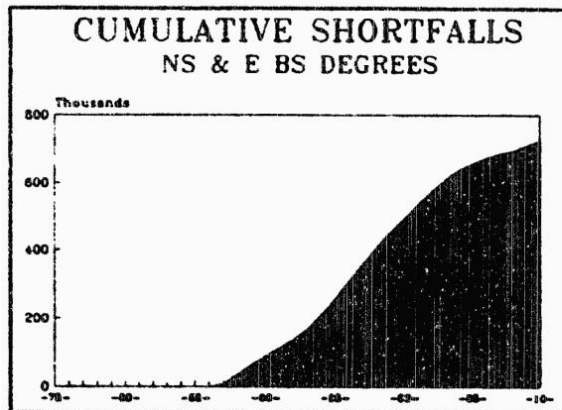


Figure 4

percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new S&E Ph.D.s was 29 to 30 years old during the 1960s and 1970s, but this has drifted up over the last 5 years to about 31 years old in 1987.

Two major reasons for a weaker population-degree link to the Ph.D. degree production are the greater importance of specific economic considerations and immigrations of graduate students in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. Ph.D. production in natural science and engineering approximately tripled between 1960 and 1972, dropped gradually in the late seventies, then slowly recovered, though not quite to the 1972 level. Most of this recovery, particularly recently, is due to a rise in Ph.D.s conferred to foreign citizens who are in the United States on a temporary basis. On the average, across all NS&E fields, the U.S. retains about half of the foreign-born Ph.D. candidates (studying in the U.S. on student visas) as members of the workforce after they finish their doctorates. Unlike its influence on B.S. degrees, Computer Science is not a major factor in the total number of Ph.D. degrees granted in NS&E (Figure 5). Demographic trends will affect future supplies of Ph.D.s

Ph.D. degree production forecasts must consider economic factors and immigration.

**FUTURE SCARCITIES OF
SCIENTISTS AND ENGINEERS:
PROBLEMS AND SOLUTIONS**

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

WORKING DRAFT

March 27, 1989

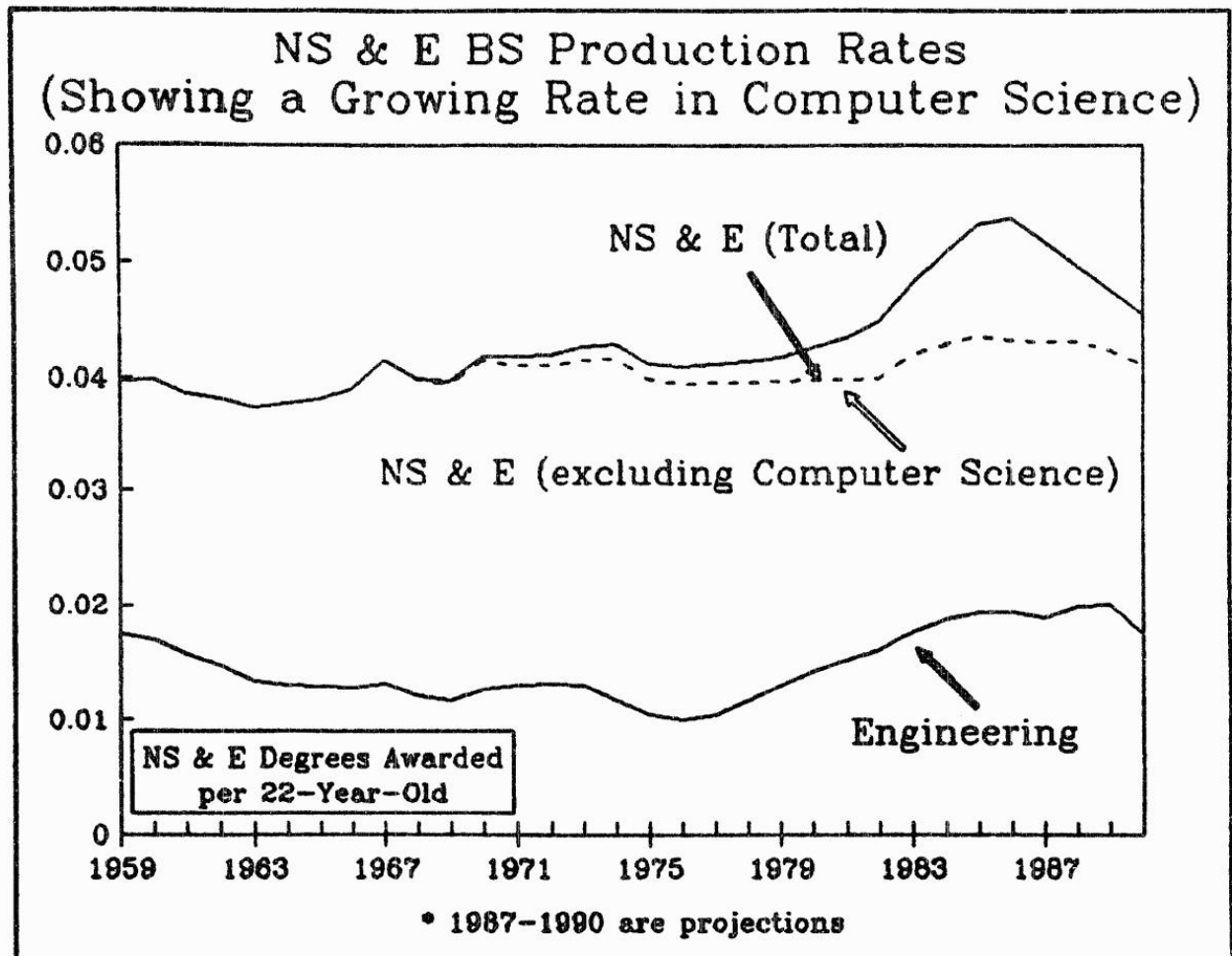


Figure 1 The recent rise in NS&E degrees was mostly due to computer science.

Most growth of computer science baccalaureates did not come from likely candidates for baccalaureates in other NS&E disciplines.

Over the past three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly. Separating NS&E into three major components (natural sciences, computer sciences, and engineering) presents very different pictures of the trend in degree production components. Natural science degrees, for example, peaked in the mid-1970s and have since been declining. Engineering degrees, on the other hand, have been increasing since the mid-1970's. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the 22-year-old population. The declared intentions of the current student body presages a decline in BS level NS&E degrees due to a reduction in the percentage of majors in NS&E fields, but the major decline is expected to be demographically driven.

Computer science degrees are less predictable. Rapid increases through 1986 appear to be devolving into rapid decreases, based on freshman intentions data (see Figure 3). Clearly the addition of computer science to other NS&E fields has made the NS&E aggregate a much less coherent set. From the early 1970s until the early 1980s, the number of individuals receiving computer science degrees was relatively small, and these students seemed to be coming from the same pool as other

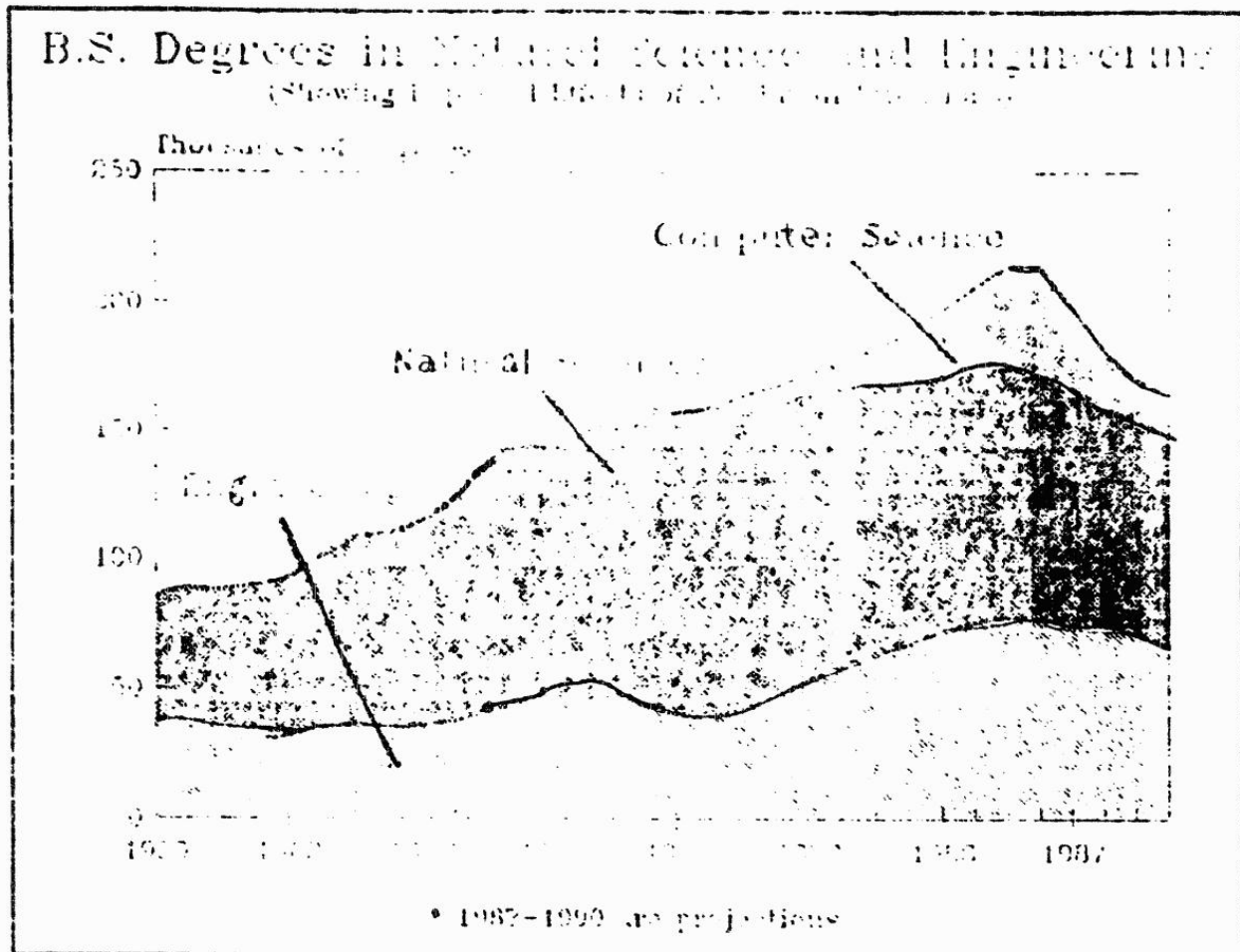


Figure 3 Choice of major field by currently enrolled students portends a decline in NS&E degrees over the next few years.

last ten years. Currently, blacks account for 13 percent of 22-year-olds but only 4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010. In summary, unless some positive action is forthcoming to overcome the observed tendencies in students' choices in courses of study, B.S. degree production in the fields of natural science and engineering will decline. It is not reasonable to expect the labor market for undergraduate degree holders in NS&E fields to solve this emerging problem, for at least two reasons. First, in the past there has been virtually no relationship between changes in the relative starting salaries for BS holders in NS&E fields (i.e., relative to other fields such as business, the social sciences and the health sciences) and the annual production of aggregate NS&E BSs, so there is no sound reason to expect market signals to expand NS&E degree production in the future. Second, in the future all professional disciplines will probably experience a reduced flow of new graduates.

The cumulative reductions in production of NS&E B.S. degrees is called a shortfall. This analysis does not attempt to forecast future demands for B.S. degree earners. The size of the problem caused by the lowered production depends on the need for such skills in the future in a healthy competitive economy. The shortfall is measured as the drop in estimated future production from the 1983 production level. If the NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the year 2006 would be about 675,000, with 275,000 being in engineering degrees (Figure 4). Even with an optimistic assumption that the demand for new degrees at the BS level will drop by 1,000 each year from 1989 to 2006 due to improved utilization and productivity of the NS&E workforce, the Nation would still face a cumulative shortfall of 440,000

***FUTURE SCARCITIES OF
SCIENTISTS AND ENGINEERS:
PROBLEMS AND SOLUTIONS***

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

**WORKING DRAFT
April 4, 1989**

The NS&E Pipeline

Several national economic indicators imply a continued growth in demand for scientists and engineers for the foreseeable future. At the same time, demographic data indicate a probable decline in the nation's production of college graduates with those skills. This paper specifies the size and nature of shortages which are likely to occur in the absence of substantial changes in young people's career choices, and examines several generic strategies which might attract and retain more students for science and engineering. At the Ph.D. level, this paper considers various strategies for increasing U.S. degree production, including additional graduate fellowship programs. The analysis of future Ph.D. labor markets compares equilibrium levels of Ph.D.'s hired and Ph.D. salaries in a variety of future settings.

Projected demand for scientists and engineers is up while projected supply is down.

Under the current apprenticeship system of graduate education in natural science and engineering (NS&E), research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality of research performed cannot be considered separately from concerns about the demand for and supply of researchers. The following analyses have used trend projections or past relationships between variables only if these are stable in the sense that have held for years (in a few cases, decades). All such assumptions about the persistence of past trends and relationships have been identified. The analyses should be interpreted as conditional on the continuation of past trends and relationships -- they assume that social values will not suddenly change.

Long-term data suggest the percent of the college age population receiving NS&E BS degrees is unlikely to be much over 5 percent.

The discussion is focused principally on natural scientists and engineers (NS&Es), especially Ph.D. NS&Es, rather than the larger population of scientists and engineers which includes the sub-population of social and behavioral scientists. The choice of focus is based on observed differences in patterns of production and demand for NS&Es, compared to social and behavioral scientists. For the latter, production and demand are less closely linked to the health of the economy and demographic changes.

Supply: B.S. degrees

Irrespective of the many factors that enter into the choice of careers, between four and five percent of the U.S. 22-year-old age population has obtained B.S. degrees in NS&E for almost three decades (Figure 1). Although the ratio has been slightly above 5% recently, college freshman career intentions survey data predict that the ratio of annual NS&E B.S. degrees awarded to the national 22-year-old population (the average age of B.S. graduates) will fall to below 5% in 1989 and 1990. Projections in this paper use a slightly optimistic value of 5%. This estimate does not greatly overstate the near-future supply or downplay severity of forecasted shortfalls. If this participation rate remains constant as assumed, the factor controlling future supply of scientists and engineers is the size of the pool from which they are drawn (Figure 2). The decline in the number of people in the 22-year-old age group will continue until after the mid-1990s, at which time it will begin to rise. The anticipated decline in B.S. degrees has not yet been observed in actual counts, although the 1986 total was the same as in 1985. (Data for 1987 were unavailable from the Department of Education when this paper was prepared.)

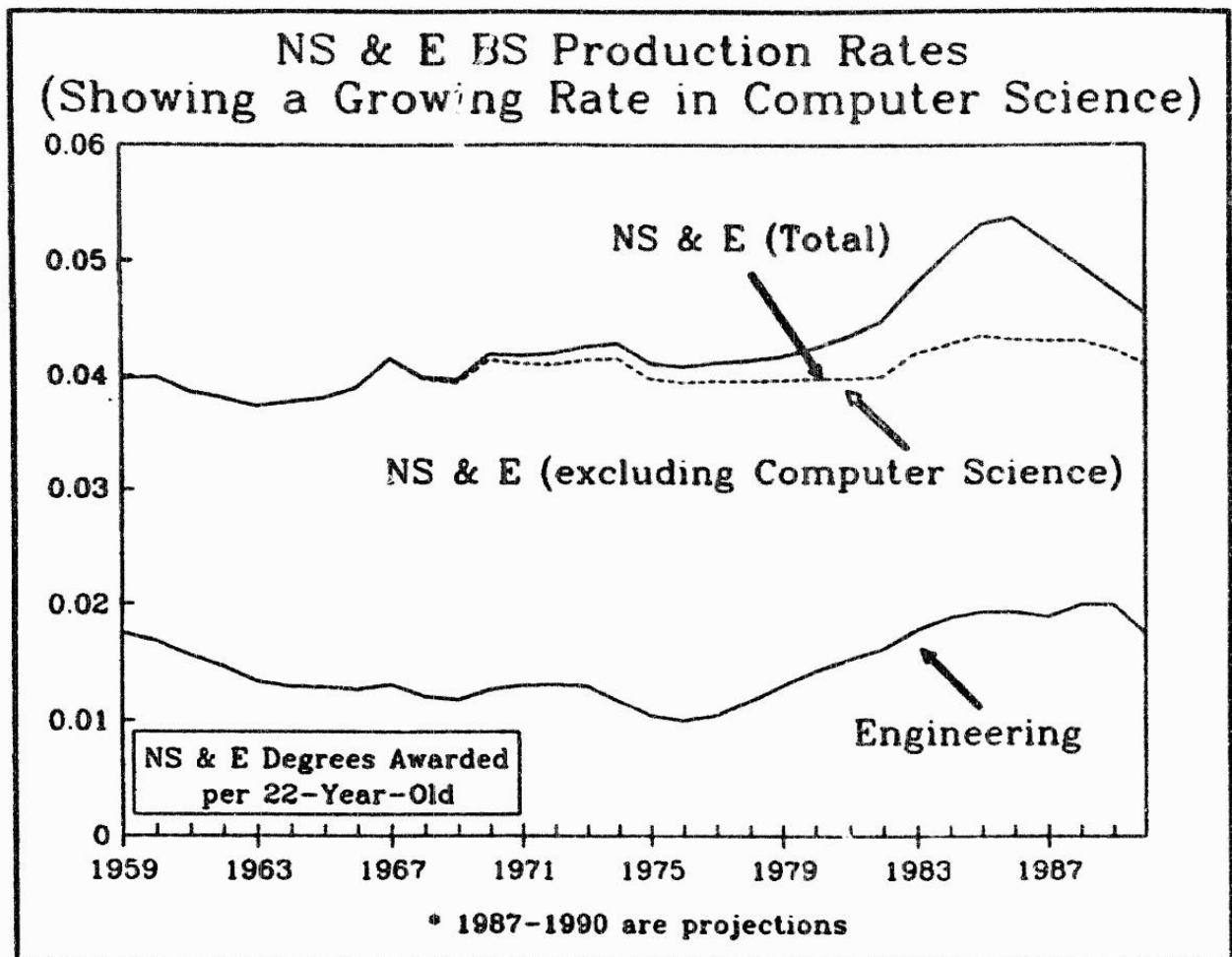


Figure 1 The recent rise in NS&E degrees was mostly due to computer science.

Most growth of computer science baccalaureates did not come from likely candidates for baccalaureates in other NS&E disciplines.

Over the past three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly. Separating NS&E into three major components (natural sciences, computer sciences, and engineering) presents very different pictures of the trend in degree production components. Natural science degrees, for example, peaked in the mid-1970s and have since been declining. Engineering degrees, on the other hand, have been increasing since the mid-1970's. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the 22-year-old population. The declared intentions of the current student body presages a decline in BS level NS&E degrees due to a reduction in the percentage of majors in NS&E fields, but the major decline is expected to be demographically driven.

Computer science degrees are less predictable. Rapid increases through 1986 appear to be devolving into rapid decreases, based on freshman intentions data (see Figure 3). Clearly the addition of computer science to other NS&E fields has made the NS&E aggregate a much less coherent set. From the early 1970s until the early 1980s, the number of individuals receiving computer science degrees was relatively

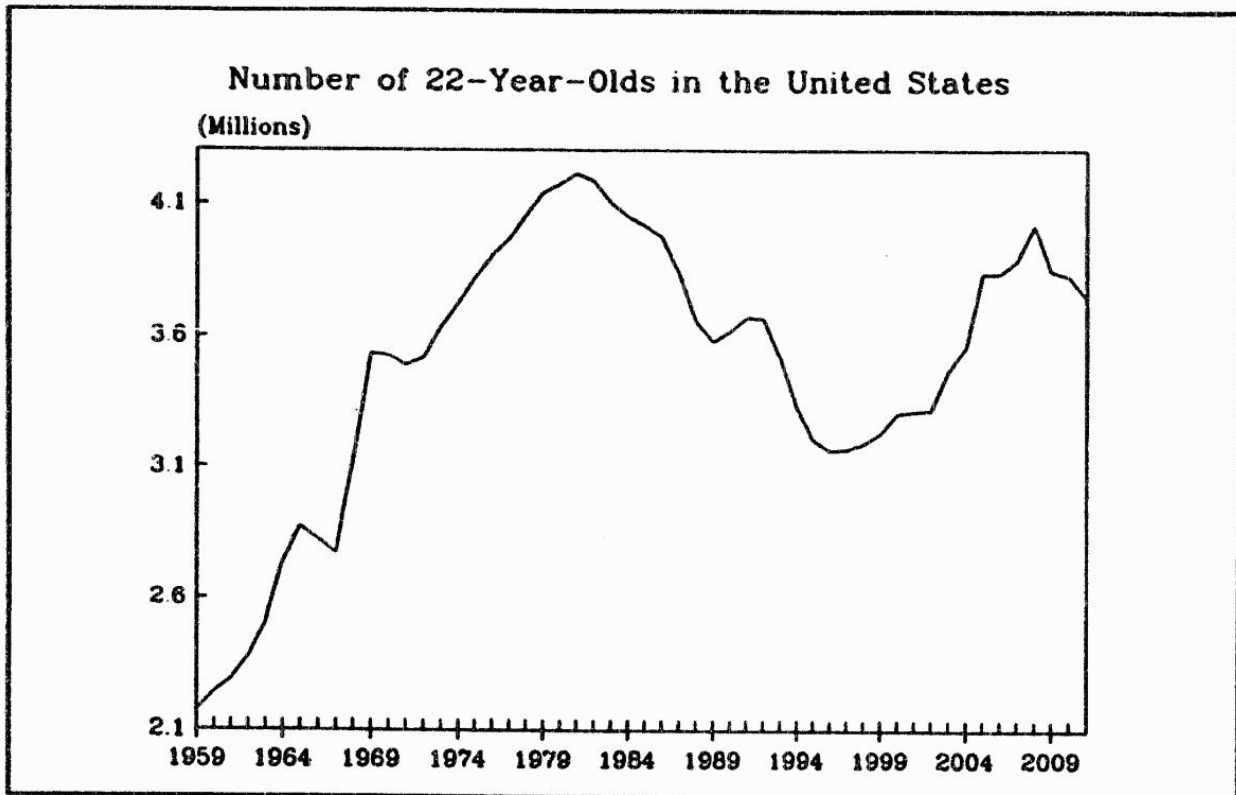


Figure 2 The dominant factor controlling NS&E B.S. degree supply is the size of the college-age population, which will decline until the late 1990's.

small, and these students seemed to be coming from the same pool as other NS&Es, particularly those interested in mathematics. Recent data, and the substantial growth in these degrees from 1980 to 1986 suggest that they have been increasing at the expense of degrees in a number of non-NS&E fields. There is some evidence that this field is attracting students that previously were not candidates for B.S. degrees.

Slow persistent growth in the rate of conferral of NS&E baccalaureates to women has been largely offset by a decline in conferral to men.

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent of female 22-year-olds in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent of male 22-year-olds in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5 percent of female 22-year-olds to 2.5 percent in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of female 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

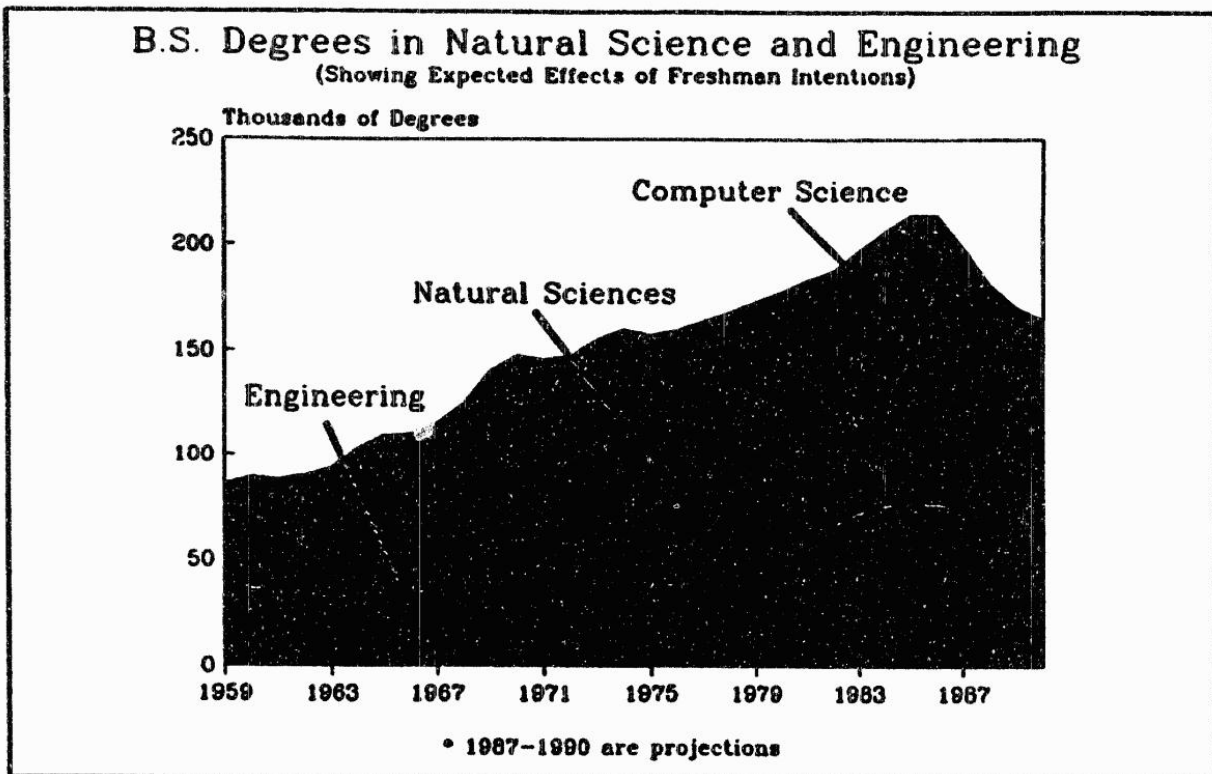


Figure 3 Choice of major fields by currently enrolled students portends a decline in NS&E degrees over the next few years.

The 5 percent conferral rate may be optimistic as a projection because underrepresented minorities have been (and are expected to continue) growing at a proportion of all 22-year-olds. The participation rate of the underrepresented minorities has been substantially below average during the last ten years. Currently, blacks account for 13 percent of 22-year-olds but only 4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010. In summary, unless some positive action is forthcoming to overcome the observed tendencies in students' choices in courses of study, B.S. degree production in the fields of natural science and engineering will decline. It is not reasonable to expect the labor market for undergraduate degree holders in NS&E fields to solve this emerging problem, for at least two reasons. First, in the past there has been virtually no relationship between changes in the relative starting salaries for BS holders in NS&E fields (i.e., relative to other fields such as business, the social sciences and the health sciences) and the annual production of aggregate NS&E BSs, so there is no sound reason to expect market signals to expand NS&E degree production in the future. Second, in the future all professional disciplines will probably experience a reduced flow of new graduates.

The cumulative reductions in production of NS&E B.S. degrees is called a shortfall. This analysis does not attempt to forecast future demands for B.S. degree earners. The size of the problem caused by the lowered production depends on the need for such skills in the future in a healthy competitive economy. The shortfall is measured as the drop in estimated future production from the 1983 production level. If the NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the year 2006 would be about 675,000, with 275,000 being in engineering degrees (Figure 4). Even with an optimistic assumption that the demand for new degrees at the BS level will drop by 1,000 each year from 1989 to 2006 due to improved utilization and productivity of the NS&E workforce, the Nation would still face a cumulative shortfall of 440,000 during this period.

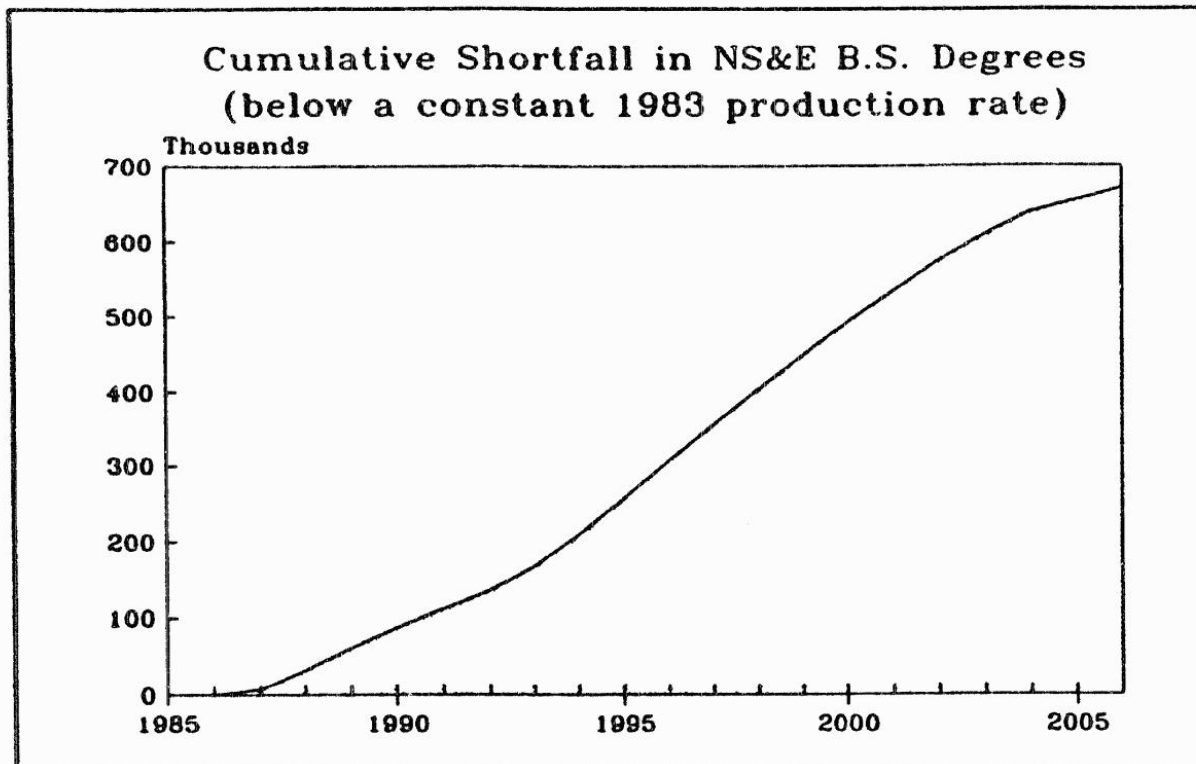


Figure 4 By 2000, the U.S. will have a cumulative shortfall of 675,000 B.S. degrees, when compared to the 1983 production level.

Supply: Ph.D. Degrees

A shortage of baccalaureate degrees also suggests a corresponding scarcity of doctorates. However, the historical link between population and degree production has not been as strong at the Ph.D. level, in contrast to the 4 to 5 percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new NS&E Ph.D.s was 29 to 30 years old during the 1960s and 1970s, but it has drifted up over the last 5 years to about 31 years old in 1987.

Ph.D. degree production forecasts must consider economic factors and immigration.

Two major reasons for a weaker population-degree link to the Ph.D. degree production are the greater importance of specific economic considerations and immigrations of graduate students in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. Ph.D. production in natural science and engineering approximately tripled between 1960 and 1972, dropped gradually in the late seventies, then slowly recovered, though not quite to the 1972 level. Most of this recovery, particularly recently, is due to a rise in Ph.D.s conferred to foreign citizens who are in the United States on a temporary basis. On the average, across all NS&E fields, the U.S. retains about half of the foreign-born Ph.D. candidates (studying in the U.S. on student visas) as members of the workforce after they finish their doctorates. Unlike its influence on B.S. degrees, computer science is not a major factor in the total number of Ph.D. degrees granted in NS&E, as shown in Figure 5. Demographic trends will affect future supplies of Ph.D.s to the extent they are dependent on baccalaureate production. Most obviously, if the rate of conferral remains fixed at 5 percent of U.S. citizens receiving baccalaureates in

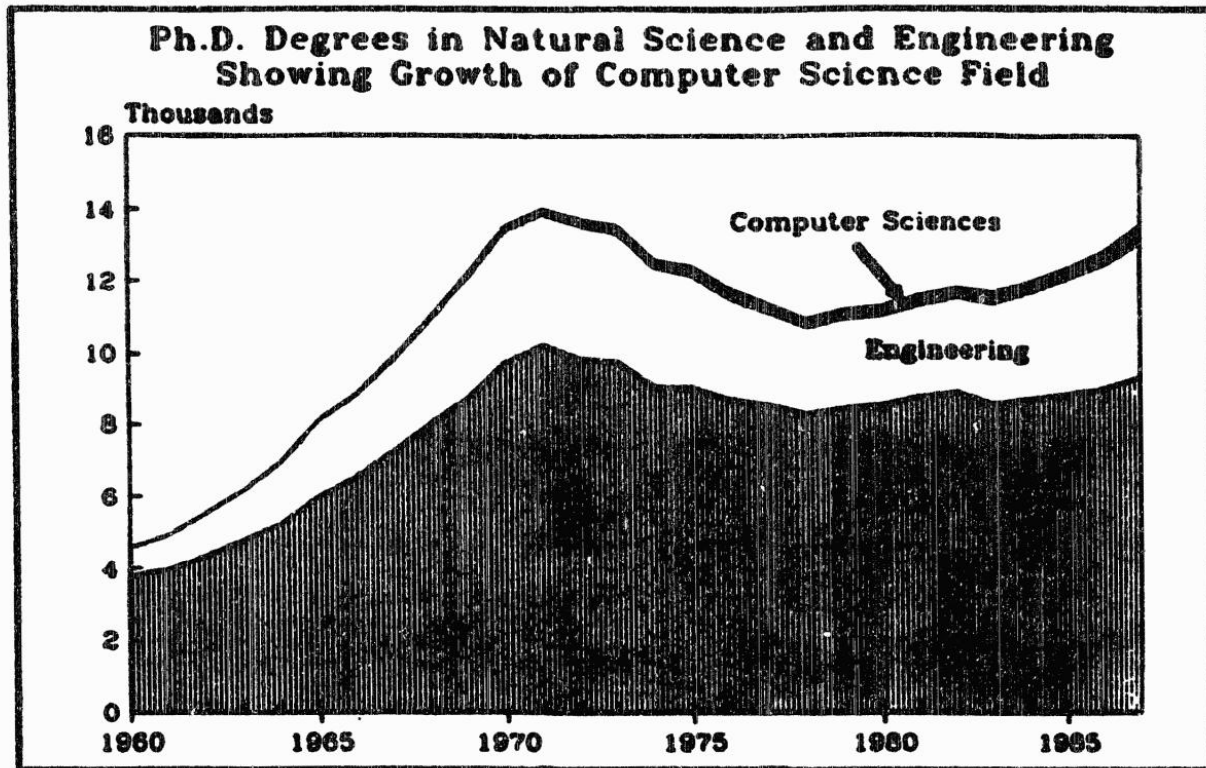


Figure 5 In 1987, NS&E Ph.D. production rates finally returned to the peak rate of 1971.

NS&E, and the number of foreign citizens remains unchanged (say at 3,800 -- slightly higher than in 1987 - as a point of discussion), then the number of new NS&E Ph.D.s will rise slightly from 13,600 in 1987 to about 15,000 in 1993 and 1994, and will subsequently decline steadily into the next century, falling below 13,000 in 2001, and approaching 12,000 in 2006, as shown in Figure 7.

On basis of baccalaureate production alone, NS&E Ph.D. production would decline by 20 percent in the decade after the mid-1990's.

Immigrants may help to compensate for the drop in Ph.D. production brought about by demographic changes in the U.S. population. Although Ph.D.s trained in foreign countries have not been a significant source of new NS&E personnel (providing only 3 to 6 percent annually since 1975), foreign doctoral students (on temporary visas) studying in U.S. universities have been a significant source of supply in NS&E fields. These foreign students accounted for more than 27 percent of NS&E Ph.D.s in 1987, and perhaps 15 percent of additions to the U.S. NS&E Ph.D. labor force.

New scientists and engineers are needed to replace those leaving the professions and to expand the growth sectors of the economy. Figure 6 shows such demands for academia, business and industry, and other (including government) sectors. Replacement is principally for retirements, which are rising in all sectors. Currently, about 5,000 positions become available annually due to deaths and retirements of NS&E Ph.D.s, including early retirements. This source of job openings is expected to rise to 6,000 in the mid-1990s and to accelerate to 8,000 at the end of this century and to 10,000 in 2006. The new position demand in each of the three sectors is driven by the rate of growth in research spending in that sector adjusted for inflation, and also by changes in enrollment in academe.

The projections shown in Figures 6, 7, 8 and 9 and the market response calculations presented below reflect the average, long-term (20-year) growth rates. These growth rates in real research spending have been 4% in industry, 3% in academe, and 1% other sectors. Corresponding sectoral growth rates in the more recent 1975 to 1987 period are 5.8%, 4.4% in academe, and 1% in other. Although a continuation

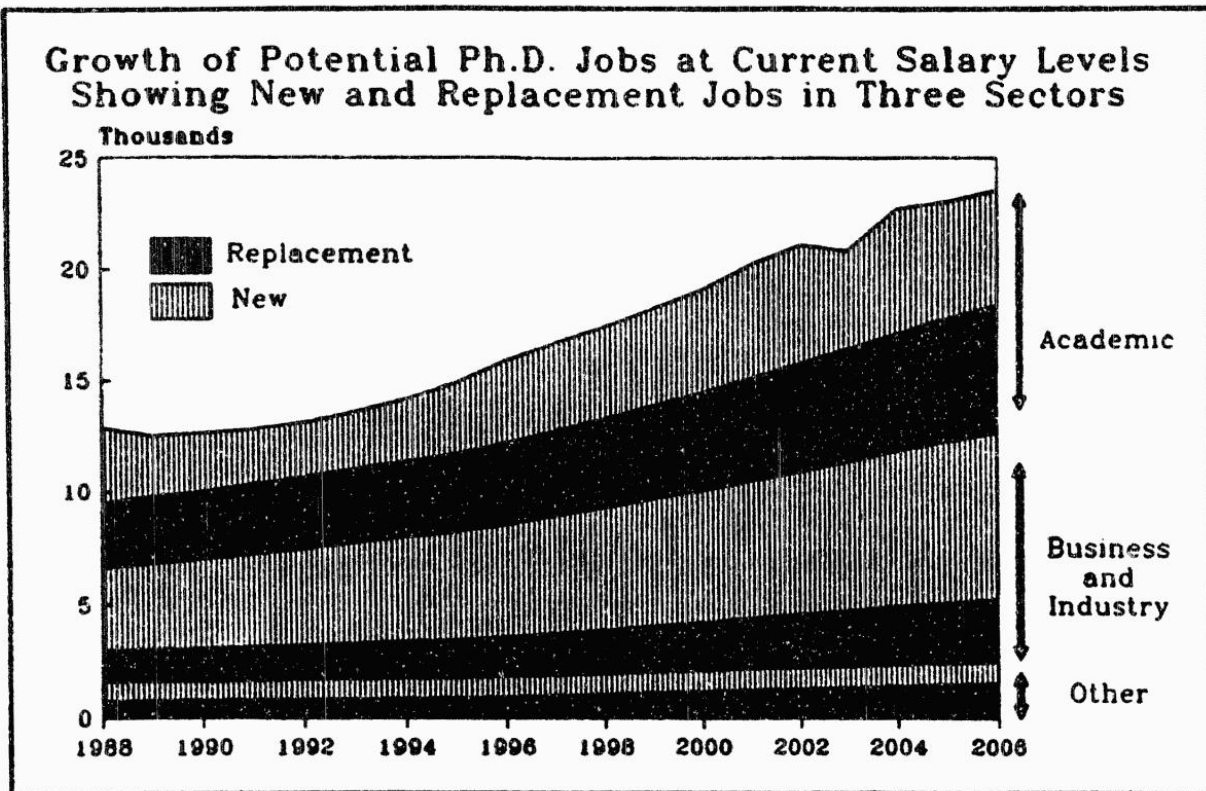


Figure 6 Over the next two decades, Ph.D. replacement needs will double in all sectors.

of these growth rates is improbable due to the large Federal share of the cost of basic and applied research (51 percent in 1987), and expected Federal fiscal austerity, future Federal research support may still continue to grow rapidly. If this scenario materializes, projected constant-salary demand would probably be much higher, as would production of American and foreign Ph.D.s.

Initially, new position demand for teaching Ph.D.s is expected to decline significantly due to falling undergraduate enrollment in NS&E degree programs. In the late 1990s, NS&E undergraduate enrollments are expected to increase once again, leading to growth in the number of new teaching positions. Overall, there are three significant components to growth in the future demand for NS&E Ph.D.s given the specification of sectoral growth rates for research: new position demand in industry, replacement demand in the academic sector, and new position demand in the academic sector. Most of the faculty hired during the boom period of the 1960s were given tenure and many are still in academe. In the middle to late 1990s, these individuals will begin to retire in large numbers with the result that the replacement demand for faculty will increase substantially, from about 2,900 at present (including early retirements) to about 5,700 in 2006. New position demand in industry is projected to grow from 3,600 to 7,400, and in academe it is expected to grow from 3,300 to 5,600.

This increasing demand in the face of a falling number of Ph.D. candidates -- assuming the present 50 percent rate of absorption of foreign students into the labor force is maintained -- would produce a substantial shortfall of doctorates starting in 1994 (see Figure 7). The most uncertain feature of this forecast is the future numbers of foreign citizens in U.S. doctoral programs and (after they have finished their doctoral work) their rate of entry into the U.S. labor force. Growth in foreign student enrollments seems likely; an increased rate of entry into the U.S. workforce is less likely because employment expansion in technological occupations in Third World Nations is likely to absorb gains in production by U.S. universities. This issue is discussed in detail later in this paper.

Market Responses to Shortfalls: General Comments

Demographically determined shortfalls can be expected to occur in most occupations, not just science and engineering. The impact is likely to be greater, however, in occupations requiring lengthier training, superior base-level abilities, and well-developed learning skills. Occupations requiring only rudimentary skill

**FUTURE SCARCITIES OF
SCIENTISTS AND ENGINEERS:
PROBLEMS AND SOLUTIONS**

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

**WORKING DRAFT
April 25, 1989**

The NS&E Pipeline

Several national economic indicators imply a continued growth in demand for scientists and engineers for the foreseeable future. At the same time, demographic data indicate a probable decline in the nation's production of college graduates with those skills. This paper specifies the size and nature of shortages which are likely to occur in the absence of substantial changes in young people's career choices, and examines several generic strategies which might attract and retain more students for science and engineering. At the Ph.D. level, this paper considers various strategies for increasing U.S. degree production, including additional graduate fellowship programs. The analysis of future Ph.D. labor markets compares equilibrium levels of Ph.D.'s hired and Ph.D. salaries in a variety of future settings.

Projected demand for scientists and engineers is up while projected supply is down.

Under the current apprenticeship system of graduate education in natural science and engineering (NS&E), research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality of research performed cannot be considered separately from concerns about the demand for and supply of researchers. The following analyses have used trend projections or past relationships between variables only if these are stable in the sense that have held for years (in a few cases, decades). All such assumptions about the persistence of past trends and relationships have been identified. The analyses should be interpreted as conditional on the continuation of past trends and relationships -- they assume that social values will not suddenly change.

Long-term data suggest the percent of the college age population receiving NS&E BS degrees is unlikely to be much over 5 percent.

The discussion is focused principally on a category called *natural* scientists and engineers (NS&Es), which excludes social and behavioral scientists. This subset of disciplines is responsible for the majority of the Nation's scientific research and development, and, as described below, is least responsive to market signals, and thus most vulnerable to future shortages.

Supply: B.S. degrees

Irrespective of the many factors that enter into the choice of careers, between four and five percent of the U.S. 22-year-old age population has obtained B.S. degrees in NS&E for almost three decades (Figure 1). Although the ratio has been slightly above 5% recently, college freshman career intentions survey data predict that the ratio of annual NS&E B.S. degrees awarded to the national 22-year-old population (the average age of B.S. graduates) will fall to below 5% in 1989 and 1990. Projections in this paper use a slightly optimistic value of 5%. This estimate does not greatly overstate the near-future supply or downplay severity of forecasted shortfalls. If this participation rate remains constant as assumed, the factor controlling future supply of scientists and engineers is the size of the pool from which they are drawn (Figure 2). The decline in the number of people in the 22-year-old age group will continue until after the mid-1990s, at which time it will begin to rise. The anticipated decline in B.S. degrees has not yet been observed in actual counts, although the 1986 total was the same as in 1985. (Data for 1987 were unavailable from the Department of Education when this paper was prepared.)

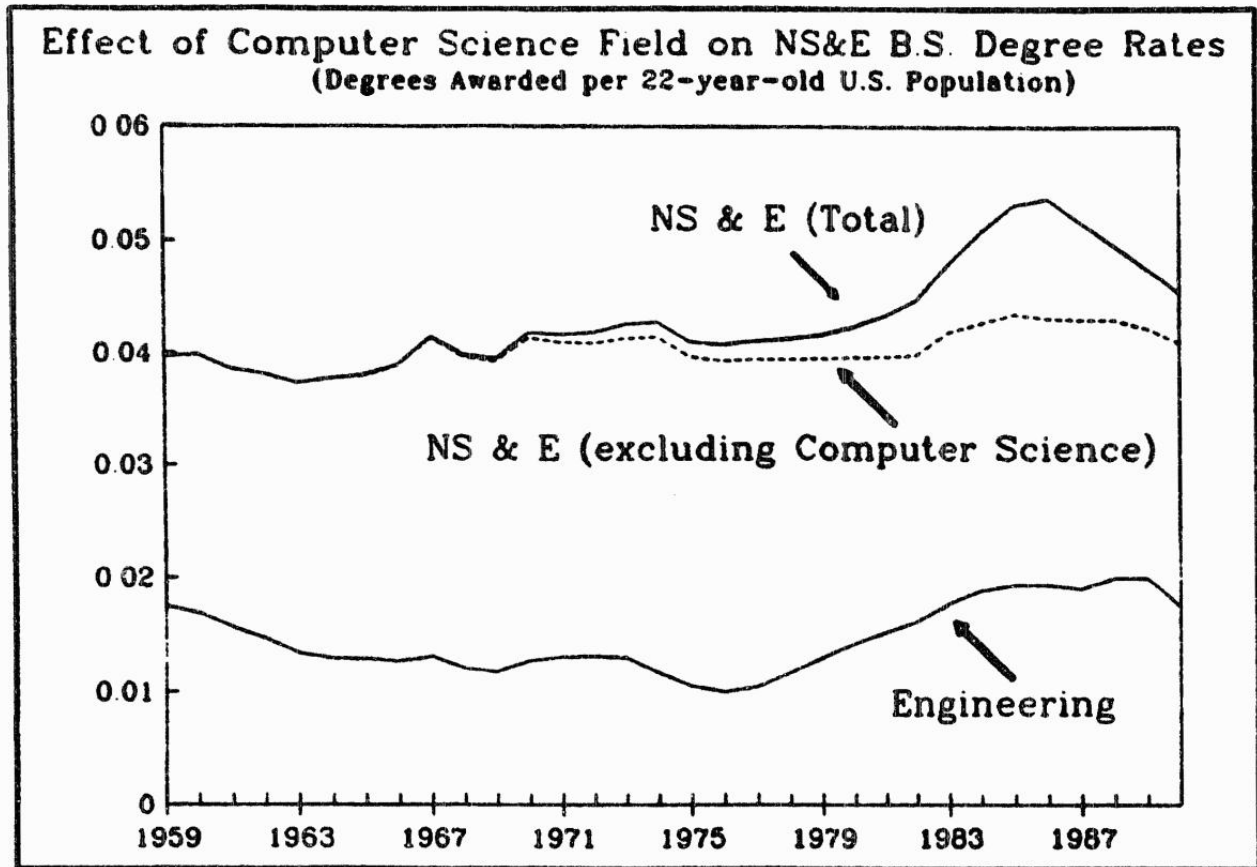


Figure 1 The recent rise in NS&E degrees was mostly due to computer science.

Most growth of computer science baccalaureates did not come from likely candidates for baccalaureates in other NS&E disciplines.

Over the past three decades, the number of baccalaureate degrees in natural science and engineering has increased steadily with population, but the growth of the individual components has shifted significantly. Separating NS&E into three major components (natural sciences, computer sciences, and engineering) presents very different pictures of the trend in degree production components. Natural science degrees, for example, peaked in the mid-1970s and have since been declining. Engineering degrees, on the other hand, have been increasing since the mid-1970's. The combined fields show a considerably modulated growth which has been consistently between 4 and 4.5 per cent of the 22-year-old population. The declared intentions of the current student body presages a decline in BS level NS&E degrees due to a reduction in the percentage of majors in NS&E fields, but the major decline is expected to be demographically driven.

Computer science degrees are less predictable. Rapid increases through 1986 appear to be devolving into rapid decreases, based on freshman intentions data (see Figure 3). Clearly the addition of computer science to other NS&E fields has made the NS&E aggregate a much less coherent set. From the early 1970s until the early 1980s, the number of individuals receiving computer science degrees was relatively small, and these students seemed to be coming from the same pool as other NS&Es, particularly those interested in mathematics. Recent data, and the substantial growth in these degrees from 1980 to 1986 suggest that they have been increasing at the expense of degrees in a number of non-NS&E fields. There is some evidence that this field is attracting students that previously were not candidates for B.S. degrees.

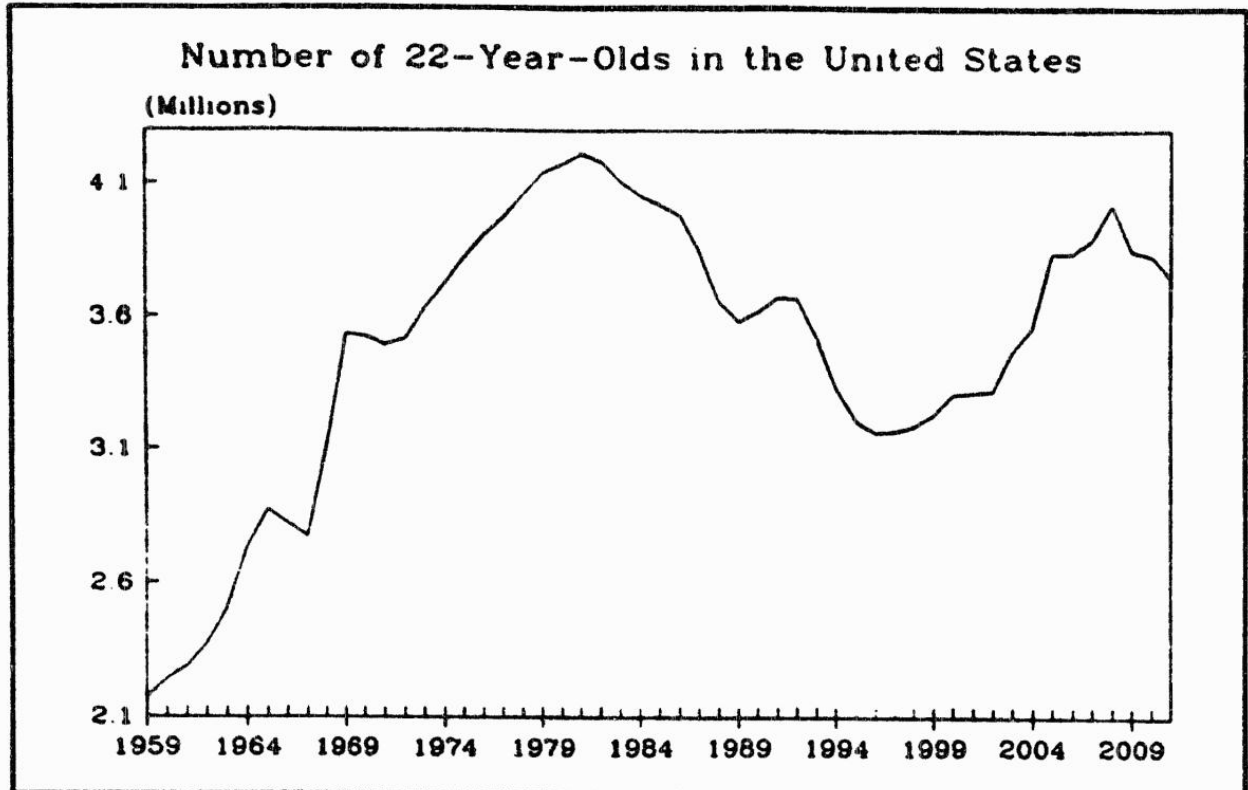


Figure 2 The dominant factor controlling NS&E B.S. degree supply is the size of the college-age population, which will decline until the late 1990's.

Slow persistent growth in the rate of conferral of NS&E baccalaureates to women has been largely offset by a decline in conferral to men.

Two other points are noteworthy. There has been a slow but persistent rise in the rate of conferral of baccalaureate degrees to women in traditional NS&E fields, from less than 1 percent of female 22-year-olds in 1959 to 2.5 percent in 1986. This rise has been offset in large measure by a decline in the conferral rate to males, from 7 percent of male 22-year-olds in the early 1970s to 6 percent in recent years. Between 1972 and 1982 new female baccalaureates in NS&E fields grew steadily from 1.5 percent of female 22-year-olds to 2.5 percent in 1982, but in the first five years the growth was entirely in life science, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-86, female NS&E baccalaureates rose to 3.3 percent of female 22-year-olds, with the growth almost entirely in computer science. B.S. degrees in computer science, the new NS&E field, have risen very fast during the 1980s. The conferral rate in this field alone was only 0.3 percent in 1980, compared to over 1 percent in 1986. The 1986 conferral rate to women in this field alone was equivalent to the rate in all other NS&E fields combined in 1959 (0.8 percent).

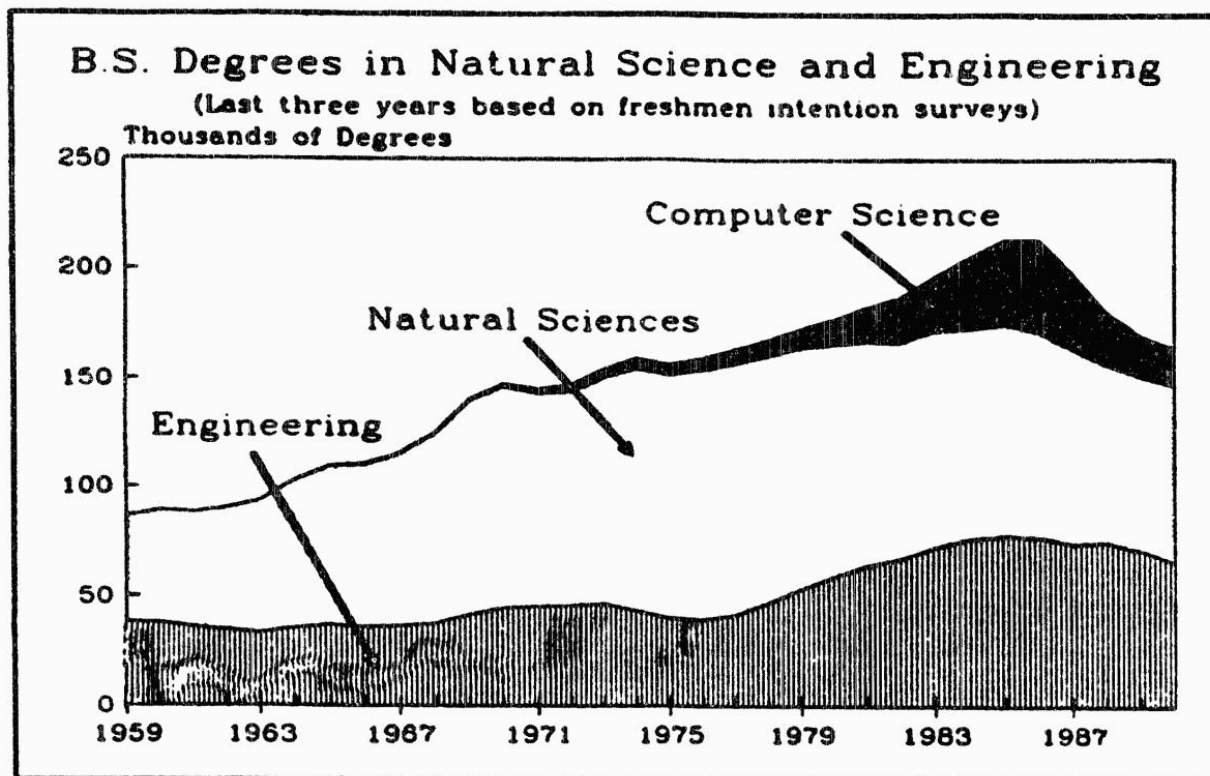


Figure 3 Choice of major fields by currently enrolled students portends a decline in NS&E degrees over the next few years.

The 5 percent conferral rate may be optimistic as a projection because underrepresented minorities have been (and are expected to continue) growing at a proportion of all 22-year-olds. The participation rate of the underrepresented minorities has been substantially below average during the last ten years. Currently, blacks account for 13 percent of 22-year-olds but only 4 percent of NS&E B.S. degrees, and Hispanics account for 7.5 percent of 22-year-olds, but only 2.5 percent of NS&E B.S. degrees. College age blacks and Hispanics are expected to increase their proportion of the total college age population from 20 percent currently to 25 percent in 1996, and 33 percent in 2010. In summary, unless some positive action is forthcoming to overcome the observed tendencies in students' choices in courses of study, B.S. degree production in the fields of natural science and engineering will decline. It is not reasonable to expect the labor market for undergraduate degree holders in NS&E fields to solve this emerging problem, for at least two reasons. First, in the past there has been virtually no relationship between changes in the relative starting salaries for BS holders in NS&E fields (i.e., relative to other fields such as business, the social sciences and the health sciences) and the annual production of aggregate NS&E BSs, so there is no sound reason to expect market signals to expand NS&E degree production in the future. Second, in the future all professional disciplines will probably experience a reduced flow of new graduates.

The cumulative reductions in production of NS&E B.S. degrees is called a 'shortfall'. This analysis does not attempt to forecast future demands for B.S. degree earners. The size of the problem caused by the lowered production depends on the need for such skills in the future in a healthy competitive economy. The shortfall is measured as the drop in estimated future production from the 1983 production level. If the NS&E participation rate remains at 5% of the 22-year-old population, the cumulative shortfall of B.S. degrees to the year 2006 would be about 675,000, with 275,000 being in engineering degrees (Figure 4). Even with an optimistic assumption that the demand for new degrees at the BS level will drop by 1,000 each year from 1989 to 2006 due to improved utilization and productivity of the NS&E workforce, the Nation would still face a cumulative shortfall of 440,000 during this period.

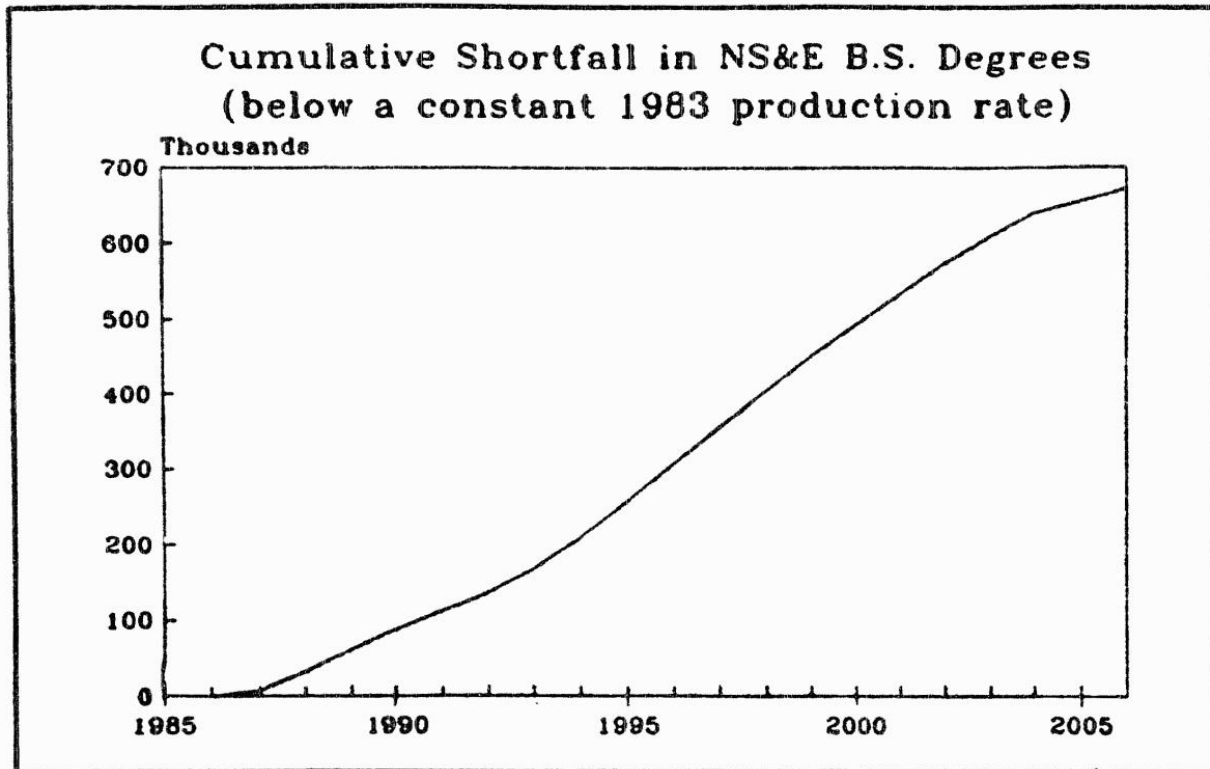


Figure 4 By 2000, the U.S. will have a cumulative shortfall of 675,000 B.S. degrees, when compared to the 1983 production level.

Supply: Ph.D. Degrees

A shortage of baccalaureate degrees also suggests a corresponding scarcity of doctorates. However, the historical link between population and degree production has not been as strong at the Ph.D. level, in contrast to the 4 to 5 percent link between B.S. degrees in traditional fields of NS&E and 22-year-olds. Part of the reason is the wide age distribution of Ph.D. recipients (90 percent of whom are 25 to 37 years old) compared to B.S. recipients (90 percent of whom are 21 to 24 years old). The median age of all new NS&E Ph.D.s was 29 to 30 years old during the 1960s and 1970s, but it has drifted up over the last 5 years to about 31 years old in 1987.

Ph.D. degree production forecasts must consider economic factors and immigration.

Two major reasons for a weaker population-degree link to the Ph.D. degree production are the greater importance of specific economic considerations and immigrations of graduate students in determining the number of Ph.D. students. Both favorable expected job availability and improved salary prospects will increase the rate of enrollment in Ph.D. programs from a given number of B.S. degree holders. Ph.D. production in natural science and engineering approximately tripled between 1960 and 1972, dropped gradually in the late seventies, then slowly recovered, though not quite to the 1972 level. Most of this recovery, particularly recently, is due to a rise in Ph.D.s conferred to foreign citizens who are in the United States on a temporary basis. On the average, across all NS&E fields, the U.S. retains about half of the foreign-born Ph.D. candidates (studying in the U.S. on student visas) as members of the workforce after they finish their doctorates. Unlike its influence on B.S. degrees, computer science is not a major factor in the total number of Ph.D. degrees granted in NS&E, as shown in Figure 5. Demographic trends will affect future supplies of Ph.D.s to the extent they are dependent on baccalaureate production. Most obviously, if the rate of conferral remains fixed at 5 percent of U.S. citizens receiving baccalaureates in

***FUTURE SCARCITIES OF
SCIENTISTS AND ENGINEERS:
PROBLEMS AND SOLUTIONS***

NATIONAL SCIENCE FOUNDATION

**Directorate for Scientific, Technological
and International Affairs**

Division of Policy Research and Analysis

The NS&E Pipeline

Several national economic indicators imply a continued growth in demand for scientists and engineers for the foreseeable future. At the same time, *analyses of student choice of college major and demographic data discussed in this paper* indicate a probable decline in the nation's production of college graduates with those skills. *Even allowing for some excess during the last decade in the number of new graduates over the number needed to fill occupations requiring training in the natural sciences and engineering, a growing scarcity will develop in the 1990s.* This paper specifies the size and nature of *scarcities* which are likely to occur at *both the B.S. and Ph.D. level* in the absence of substantial changes in young people's career choices, and examines several generic strategies which might attract and retain more students for science and engineering. *At the Ph.D. level, this paper considers various strategies for increasing U.S. degree production, including additional graduate fellowship programs.*

The analysis of B.S. degree production focuses on the evident limited response of aggregate NS&E degrees to market signals. Also considered to come extent is the flow of students through the high school and college "pipeline" and the attendant losses of potential natural scientists and engineers. The analysis of future Ph.D. labor markets compares equilibrium levels of Ph.D.'s hired and Ph.D. salaries in a variety of future settings.

Projected demand for scientists and engineers is up while projected supply is down.

~~Under the current apprenticeship system of graduate education in natural science and engineering (NS&E), research and the next generation of researchers are jointly produced. Thus, concerns about the amount and quality of research performed cannot be considered separately from concerns about the demand for and supply of researchers. The analyses in this paper have used trend projections or past relationships between variables only if these are stable in the sense that they have held for years (in a few cases, decades). All such assumptions about the persistence of past trends and relationships have been identified. The analyses should be interpreted as conditional on the continuation of past trends and relationships -- they assume that social values will not suddenly change.~~

Long-term data suggest the percent of the college age population receiving NS&E BS degrees is unlikely to be much over 5 percent.

The discussion is focused principally on ~~a category called~~ *natural scientists and engineers (NS&Es), rather than the larger population of scientists, which includes the sub-population of social and behavioral scientists. This subset of disciplines is responsible for the majority of the Nation's scientific research and development, and, as described below, is least responsive to market signals, and thus most vulnerable to future shortages. The choice of focus is based on observed differences in*