- Every effort will be made to adhere to the agreed upon production schedule specified earlier in the process.

External review. External review is a vital part of the production of any body of professional literature, and SRS reports are not only professional in their importance and content, but of vital interest to our attendant publics in the Executive Branch, the Congress, professional associations, the higher education community, nonprofit organizations, and industry. External review will assure that our reports are standard authorities in these circles.

- The extent of external review will be specified in the review procedure and production schedule, and will vary from document to document, with the same or very similar procedures and schedule pertaining to similar reports. Some documents may not be subjected to external review at all; examples might include early release tables and similar noninterpretive documents.

- In consultation with the Assistant Director/STIA, the STIA Advisory Committees, and outside organizations, an Editorial Board for our publications will be established, representing the broad array of skills and expertise in our work.

- Under most circumstances, two persons will be selected from this Board by the Office of the Division Director to review a document that is submitted to external review, and the external review plan will be included as part of the review procedure and production schedule.

- External reviewers will be asked to focus their attention on substantive concerns, with technical editing to remain the province of our own editorial capabilities. External reviewers will be asked to provide comments in writing, and will be given clear deadlines.

- External reviewers' comments will normally be considered in a conference including the Office of the Division Director, Program Director, Publications Manager, and author(s). On some occasions, however, the comments may be so limited that a meeting may not be necessary.

- Documents such as Detailed Statistical Tables may be handled differently. For example, the Office of the Division Director may elect to have them reviewed in groups periodically with the goal of improving the general approach of the presentation, as opposed to addressing the particularities of a specific report.

- Publications prepared or edited under the guidance of outside contractors are subject to the same review procedures as those prepared or edited internally.

STIA role. The Assistant Director/STIA is responsible for all of our publications, and hence, has an important and legitimate role in our review process. However, the institution of a systematic external review procedure, supported by a functional SRS Editorial Board, will vitiate the need for detailed and time-consuming STIA reviews. It is anticipated that such reviews will become *pro forma*.

The Division Director will bring to the notice of the Assistant Director/STIA any aspect of a publication that merits special attention. In particular, reports that have substantial public policy content and include include controversial information will be highlighted.

(2) Physical production

General. SRS should make every effort to streamline the production of manuscripts.

- Text, graphics, and tables prepared by authors or other staff may be initially generated either by hand or by computer, depending on the skill level and preference of the author. But before they are passed on for editing, they must be in machine readable format on diskettes or, when we have determined how to do this, on the network.
- Survey contractors or SRS staff will be expected to produce camera ready tables for Detailed Statistical Tables and appendices for reports.

Release of data. We will be generating a clear policy on the release of data that will be fully cognizant of relevant law, regulations, and practices. Until we have that in place, we will continue to do all data releases on an *ad hoc* basis, with guidance from Donna Fossum, the Acting Deputy Division Director.

[end]

ADVISORY COMMITTEE MEETING
DIRECTORATE FOR SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

Summary of Meeting
March 28, 1991
National Science Foundation
1800 G Street, N.W., Room 1242
Washington, D.C. 20550

Committee Members Present

Dr. Albert Westwood, Martin Marietta Corporation, Chairman
Dr. Fernando Agrait, University of Puerto Rico
Mr. Jesse Ausubel, The Rockefeller University
Dr. Alfred Blumstein, Carnegie-Mellon University
Dr. Alfred Brown, Independent Consultant
Dr. Naomi E. Collins, Maryland Humanities Council
Mr. Edward L. Glaser, Nucleus International Corporation
Dr. Sidney Green, TerraTek, Inc.
Dr. Charlotte V. Kuh, Educational Testing Service
Dr. Shirley Malcolm, American Association for the Advancement of Science
Dr. Edward Miles, University of Washington
Dr. William Sibley, University of Alabama at Birmingham
Dr. Albert Teich, American Association for the Advancement of Science
Dr. Katherine Wallman, Council of Professional Associations on Federal Statistics

Committee Members Absent

Dr. Thomas Cole, Clark-Atlanta University
Dr. Robert Herman, University of Texas
Dr. H. Guyford Stever, Corporate Director & Science Advisor

Executive Secretary
Dr. Marta Cehelsky

Guests

Dr. Lynne Cheney, Chairman, National Endowment for the Humanities
Dr. Walter Massey, Director, NSF

Participating NSF Staff

Karl Willenbrock
Assistant Director, STIA

Rose Bader
Bill Blanpied
Jennifer Bond
Dick Bradshaw
Joe Danek
Alex DeAngelis
Gerard Glaser
Daryl Gorman
Peter House
Len Lederman
Dan Melnick
Vanessa Richardson
Gerson Sher
Don Senich
Bonnie Thompson
Richard Ries
Pat Tsuchitani

The third meeting of the Scientific, Technological, and International Affairs Advisory (STIA) Committee (AC-STIA) focused on science and technology (S&T) in the European Community (EC), data and policy analysis activities, and STIA mission statements. Special guest Lynne Cheney, Chairman of the National Endowment for the Humanities, and NSF's new Director, Walter Massey, joined the Committee for a luncheon discussion.

Committee Chairman Bert Westwood opened the meeting and reviewed issues and recommendations that emerged from the previous meeting of the Committee. Edward Miles and Alfred Brown reported on the activities of the Advisory Committees on International Affairs and Small Business Innovation Research (SBIR), respectively.

STIA Assistant Director Karl Willenbrock noted several personnel changes in NSF -- in particular Walter Massey's confirmation as Director of NSF. Marta Cehelsky has accepted a temporary appointment as Dr. Massey's special assistant for issues and policy; Jeanne Hudson will assume the responsibility of executive secretary to the Advisory Committee.

TOPIC: SCIENCE AND TECHNOLOGY IN THE EUROPEAN COMMUNITY

Karl Willenbrock noted the growing importance of European science and technology activities and the need to define a comprehensive NSF agenda in response to the new opportunities and challenges.

Rich Ries, Director of the Division of International Programs (INT) outlined the elements of an emerging "European strategy" based on a Europe-wide perspective, and a stronger regional emphasis. Important elements of the emerging strategy are: (1) monitoring the changing S&T policy environment, (2) facilitating the two-way flow of scientists and engineers, (3) greater focus on young investigators, and (4) stronger emphasis on aggregating limited resources.

The Committee pointed to the need for better mechanisms for capturing, disseminating, and (commercially) exploiting the information gained from these exchanges. The Committee also pointed to the need for careful evaluation of bilateral S&T agreements and activities, including the relative merits of different agreements -- for example, an assessment of the heavy focus on France.

Recommendation:

o STIA should explore mechanisms to capture the synergistic benefits of bilateral agreements -- for example, holding annual workshops for persons participating in bilateral exchanges, or publishing "Notes From Abroad" equivalent to those published by ONR but more broadly circulated (at present such NSF notes are sent only to universities and do not reach researchers in industry or national laboratories).

Dick Bradshaw of INT reviewed two recent reports on science and technology in the European Community. The role of EC S&T institutions is primarily to encourage and coordinate transnational linkages, and most of the limited funds available go to applied R&D and commercialization. A reevaluation of these efforts is currently underway and may lead to a reduction in funding for existing large-scale EC programs, in favor of greater emphasis on strengthening S&E education and building electronic information networks.

These trends create opportunities for U.S.-EC cooperation in four areas: transnational centers of excellence; a common electronic information network; the development of human resources; and joint initiatives in Central and Eastern Europe. NSF is already a player in U.S.-EC initiatives in global warming, megascience, and biotechnology. Both the National Science Board and FCCSET/CISET reports recommend expanded, institutionalized NSF contacts with, and information-gathering in, the EC.

Committee members urged caution in developing umbrella agreements with the EC, because the situation within Europe is not yet clearly resolved. NSF should not lock itself in too early on specific agreements, nor should it give credibility to specific EC organizations before they have constituent support in Europe. The Committee suggested that NSF-STIA develop guidelines for consideration by the U.S.-E.C. Joint Consultative Group to ensure that NSF's opinions and concerns are properly reflected in future discussions.

Recommendation:

o STIA-INT should identify and publicize activities throughout NSF that demonstrate the domestic, commercial benefits of international cooperation in S&T.

Rod Nichols, Scholar in Residence at the Carnegie Commission on Science, Technology, and Government presented the findings and recommendations of the Commission's draft report, Enabling Modern Diplomacy. It concludes that the Federal Government does not tap the Nation's available technical resources for planning and conducting U.S. foreign policy, and that the Department of State must play a more focused and effective role in support of the nation's science and technology agenda. The report makes several recommendations:

- o Immediate needs include better policy coordination among agencies and between the Administration and Congress, as well as a stronger role by the Office of Science and Technology Policy (OSTP);
- o new measures could include "mainstreaming" international S&T programs into the S&T agencies,
- o strengthening science bureaus in the Department of State, establishing the post of Science Advisor to the Secretary, and increasing the number of science counselors abroad.

Tom Owens reported on his experience in running the NSF European Office in Paris. In a period of five months he wrote about 20 reports, often for other NSF directorates, and believes that there are far more needs than one person can satisfy. His efforts were often complicated by State Department requirements and resource constraints. NSF staff in Paris could do a better job, but this would require additional resources that are not forthcoming under current institutional arrangements spelled out in Marta Cehelsky's paper on the NSF experience in Europe.

The Committee concluded that the constraints that the State Department places on NSF-Paris make it difficult for it to conduct its business in Europe -- namely the collection of scientific and technical information and program implementation, and that a new approach is needed. The Chairman expressed concern that the US has difficulty placing technically competent personnel around the world as U.S. competitors are doing. The Committee discussed the establishment of NSF offices in multiple locations overseas, and expressed its willingness, at Dr. Willenbrock's discretion, to make recommendations to the Director of NSF. The Committee concluded that an integrated approach, involving both NSF and other scientific agencies (e.g., DOD, DOC, EPA, NIH), would be more effective.

Recommendation:

o NSF should pursue the issue of its presence abroad with OSTP and other Federal science and technology agencies, with the objective of having Alan Bromley, the President's Science Advisor, explore with Secretary of State James Baker how the technical community can best serve the interests of the United States.

LUNCHEON GUEST: DR. LYNNE CHENEY, Chairman of the National Endowment for the Humanities

Dr. Naomi Collins, who at the last meeting had raised the issue of public programming to increase the number of scientists and engineers, introduced Dr. Lynne Cheney, Chairman of the National Endowment for the Humanities (NEH). Dr. Walter Massey, newly appointed Director of the National Science Foundation, joined the Committee for lunch and expressed his appreciation for its efforts.

Dr. Cheney noted that the sciences and the humanities face common problems, including: encouraging an intelligent citizenry, increasing the pool of practitioners, reversing the decline in undergraduate enrollments, providing K-12 teachers who know their subject, and providing in-service training for teachers (e.g., summer institutes). NEH has successfully addressed these problems through outreach programs, including the creation of Humanities Councils in every State and Territory and "public programming" (e.g., television programs, museum shows, touring exhibits, and local seminars).

The Committee saw several opportunities for collaboration between NSF and NEH, notably in improving the effectiveness of general education in addressing the broader social aspects of science; all of the 17 EPSCoR States, for example, have public education and awareness programs for S&T. Dr. Cheney also distributed copies of <u>50 Hours: A Core Curriculum for College Students</u>, which addresses not only what science all students should study, but also what scientists should study.

TOPIC: STIA DATA AND POLICY ACTIVITIES

In its first meeting, AC-STIA identified data and policy analysis as an area of great importance and potential concern. Since that time STIA has brought in new personnel, convened a new Advisory Committee on Data and Policy Analysis (ACDPA), and explored ways to work with other NSF directorates -- Education and Human Resources (EHR) and Biological, Behavioral and Social Science (BBS) -- and the external community to increase the credibility of data quality and analysis. Dr. William Ellis, on loan from The Congressional Research Service (CRS) as Acting Director of Science Resources Studies (SRS), discussed activities undertaken to increase the structural and operational interactions between STIA and EHR.

The Chairman commented that STIA may wish to evaluate the proposition that what the Nation actually needs is not more scientists and engineers, but rather a more technically competent <u>workforce</u> -- a new class of "professional technical specialists," equivalent to the craftsmen of an earlier era, one step below the State-registered Professional Engineers -- capable of translating the developments of science and technology into high- quality, competitive products. A corollary question is whether the Nation now needs a revitalized technical high school system and/or a system of apprenticeships to develop flexible, quality-conscious technical workers.

Katherine Wallman, a member of the ACDPA, reporting for that committee's chairman, Judith Liebman, noted that in its two meetings, ACDPA has focused on questions of balance, such as responding to the legitimate demand for information while ensuring the validity, reliability, and credibility of the data being used. Major issues are:

1. increased coordination with other Federal statistics agencies;

2. predictable and transparent analytical procedures;

3. development and implementation of a comprehensive "portfolio review" of SRS and PRA activities;

4. definition of appropriate principles and procedures for various data collection and analysis activities by Policy Research and Analysis (PRA);

5. insuring quality and credibility.

The forthcoming tenth edition of Science and Engineering Indicators provides an opportunity for initiatives in this area, including negotiations with Congress as well as a special conference addressing these and other questions relating to data and policy analysis.

The Committee suggested that ACDPA consider what STIA's SRS and PRA divisions might accomplish given both technical and financial limitations. AC-STIA also noted that ACDPA might recommend priorities for PRA, and help define the boundaries of credibility of its analyses, for example, by clarifying the assumptions underlying the data and the limitations on their use and application.

AC-STIA commended the Advisory Committee on Data and Policy Analysis for its thorough and comprehensive review of STIA's data and analysis functions and for its contribution to the development of more effective bases of activity.

Recommendation:

- STIA should consider the possibility of developing a "zero base" strategic plan for Science and Engineering Indicators and identify analyses needed for the next decade --- for instance, if SRS and PRA were starting from ground zero, what could and should they do, and in what order of priority.

TOPIC: STIA MISSION STATEMENTS

Karl Willenbrock noted that in response to the STIA Advisory Committee's request, STIA has developed a mission statement, and that the STIA Divisions have developed their own individual statements. The Committee discussed the statements, offered a variety of suggestions for improvement, and specifically noted that STIA's mission statement should reflect the directorate's proven role as an incubator of successful new programs, particularly in the areas of industrial applications and relationships with the states.

Preparation

Marta Cehelsky
Executive Secretary

Approval

Albert Westwood
Chairman

MEMORANDUM

DATE: April 19, 1991

TO: Director, NSF

FROM: Division Director, PRA

SUBJECT: Quotes from the OTA Report, "Federally Funded Research in the Subject of Projecting Supply of Demand for PhD Researchers"

The recently released OTA report, "Federally Funded Research: Decisions for a Decade" comes up with the following statements about basing policy on projections of supply and demand for Phd researchers.

1. Recent projections of shortages of Ph.D. researchers in the mid-1990s have spurred urgent calls to augment Ph.D. production in the United States. OTA believes that the likelihood of these projections being realized is overstated, and that these projections alone are poor grounds on which to base public policy. For instance, they assume continued growth in demand in both academic and industrial sectors, independent of the level of Federal funding.

Based on changing demographics and historical trends in baccalaureate degrees, some studies have projected that the scientific community will face a severe shortage in its Ph.D. research work force during the 1990s.[79] However, there are pitfalls in the methodologies employed in these projections of Ph.D. employment demand.[80] Predicting the demand for academic researchers must also account for enrollment and immigration trends, anticipated career shifts and retirements, and the intentions of new entrants, as well as shifting Federal priorities and available research funding. All of these are subject to change, and may vary by institution, field, and region of the country.[81] In addition, OTA questions

the ability of statistical analyses to predict future demand for s/e Ph.D.s, especially as responses to market signals and other societal influences are known to adjust both interest and opportunities. Even without the prospect of a slackening economy in the 1990s, such projections would be unreliable. Given the track record of these forecasting tools, they are poor grounds alone on which to base public policy.[82]

An Overlooked Point About Projections of S&E Degree Production

Everyone agrees that projections of scientific manpower are not very reliable, and thus hazardous as the sole basis of policy. But overlooked in the current emphasis on these points is the success of a recent NSF projection.

Projected Downturn in NS&E Bachelors Degrees Is Happening

In 1985, PRA projected a downturn in bachelors degrees in NS&E fields, based on demography PLUS an empirical stability in the relationship between demography and one subset of S&E degrees (called NS&E). Some of the community was unconvinced, and a debate similar to today's ensued. Then, the focus was on whether there would actually be a downturn in those degrees. Now, after such a downturn has in fact occurred ('89 NS&E bachelors degrees are 15% or 30,000 fewer than in 1986, with a monotonic decline in between), the focus has (properly) shifted to whether the downturn matters. In the meantime, however, NSF should take the opportunity to note that the projection itself has NOT been overtaken by events.

In December 1985, OTA stated that if the Nation needs increasing numbers of such college graduates, "this possible decline in science and engineering baccalaureates could pose a significant problem. Fortunately, OTA finds this scenario to be unconvincing. [new paragraph] **It is entirely possible that the supply of people trained in science and engineering will not decline at all, despite the drop in the college age population."**[emphasis OTA's.][1] Other incontrovertable possibilities that might preclude a decline were then sketched. (With respect to the number of bachelors degrees produced in NS&E, the listed possibilities reduce to one: the percent of an age cohort getting such degrees might go up.)

Others took that view as well. But the decline is taking place, almost as projected. To our knowledge no one has as yet made a market-based explanation[2] of the downturn (or a prospective projection of it), during a time when the total number of bachelors degrees has kept on rising.

The 1974 NAS Seminar's Critique of Extrapolation Techniques

In her January 9th memo, Chris Wise Mohr states that "[t]he theoretical and methodological bases for the PRA analysis are essentially the same os those criticized at the NAS seminar more than a decade earlier". This is broadly true at the bachelors degree level, in that PRA's method does multiply projections of an age-specific population by "a trend projection

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[1] Technical Memorandum, Demographic Trends and the Scientific and Engineering Work Force, Office of Technology Assessment, December 1985, p.4.

[2] There has been no obvious decrease in the salary premiums for NS&E majors, nor an obvious glut of new NS&E bachelors, to send market signals back to undergraduates.

for the appropriate continuation rate (or rates)"[3]. But to leave the issue there overlooks the kernel of information contained in the PRA projection that, so far, has made its bachelors degree projection better than at least some past attempts.

The bachelor level degree projections criticized by economist Walter Oi at that seminar involved projecting the percentage of an age cohort who graduated from high school, which changes over time, then separately projecting the (changing) percentage of high school graduates who enrolled in college, separately projecting the (changing) percentage of freshmen who would graduate from college (perhaps in certain fields), and then combining the three projections and multiplying the combination by the projected cohort size. Oi has all kinds of legitimate problems with the trend estimation and the compounding methods, for which many alternatives can be proposed with quite different results. He also deplores the lack of causal understanding of the projected trends.

The PRA contribution[4] was to replace all of the estimation, projection, and compounding of noisy, little-understood time series with an empirically observed near-constant[5]. The very complications that Oi raises are the reasons that PRA never applied its method for sets of fields that seem to have a much less constant relationship between the age cohort and number of bachelors degrees. When there is little theoretical understanding of the determinants of a series, it is much easier to project a near-constant correctly than a time-varying series!

The appearance of simplism in this method, and perhaps its non-generalizability to other groups of fields, have apparently obscured its relative merits compared to other projection methods. Nevertheless, the projection it yielded is still standing up well.

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[3] Walter Oi, "Scientific Manpower Forecasts fron the Viewpoint of a Dismal Scientist",in Scientific and Technical Manpower Projections, Proceedings of the Seminar, National Science Board, October 1974 (NSB-74-287) p. 198.

[4] Myles Boylan's insight

[5] The ratio of bachelors degrees in Natural Sciences and Engineering to the number of 22-year-olds has been fairly constant for three decades. Relatedly, PRA examined market forces, and found them to explain only a tiny fraction of changes in yearly NS&E degree conferrals.

MEMORANDUM

DATE: April 24, 1991

TO: Mary L. Good
Chairman, NSB

FROM: Division Director, PRA

SUBJECT: Demographic Trends and Geographic Distribution

Per our discussions, attached are charts from two briefings recently presented to the Director. I have taken the liberty of summarizing the salient parts.

The first issue is the impact of demographics on science and engineering. As you will note we have taken a significantly different approach:

- The past thirty years have witnessed the baby boom followed by the baby bust. The impacts of the boom on society have been widely documented, and its concomitant impact on the science community (an era of great growth and institution building) is well known. The effect of the baby bust is less certain, as it is just beginning. Three areas, the shrinking of the entry level work force, its changing composition, and the aging work force, are already in the literature. The impacts on the science community were also discussed in these same areas. Over the next 20 years, there will be several million fewer people entering the workforce than entered during the previous 20 years.

- There will be fewer young people to seek college degrees. The only piece of information we have to estimate what this shrinkage might be is in the combined fields of Natural Science and Engineering. These combined fields have, for the past thirty years, seen about 5% of the matriculating age cohort going on for a NS&E degree. Unless this stable participation rate increases, the number of NS&E B.S. degrees will decline proportionately with the population cohort.

- We are not able to segregate this collection of fields to finer levels, as many disciplines (for example many of those in engineering) have been experiencing growth for the past fifteen years; other fields, for example, the natural sciences, have generally declined. Having fewer people in the future from which to recruit might reasonably be evaluated differently by these two groups.

- Fewer NS&E B.S. degrees may yield fewer NS&E Ph.D. degrees unless something occurs to encourage more NS&Es to pursue advanced degrees. This will be more or less of a problem depending upon the rate of growth of R&D in all sectors. A recent study by Baker of the NAS found that four studies of the Ph.D. issue all suggested there will be an imbalance between jobs and degrees in the future.

The second topic, geographic distribution, is one of the issues faced by all agencies. For the NSF, a stricture against "undue concentration" was entered in our founding legislation.

- There are many different levels and normalization bases from which to view the concept of "undue concentration." We discuss the state level and the university level.

- Interest at the state level is partly because of the belief that having a strong research university can contribute to economic development. This has put added pressure on the Congress for each state to get its "fair share."

- The distribution of funds from NSF is "concentrated," with states like California, New York, and Massachusetts getting a large share. The "underfunded" states are being aided in the competitive process through the EPSCoR program.

- The distribution of funds to the states is a resultant of a process that begins with individual investigators competing for funds. In the states where there is a concentration of funds, there are simply more high quality investigators, in more departments in more universities than in other states.

- At the university level, again, there is a concentration at relatively few universities. But these universities have been distinguished institutions for decades. There is little NSF has done to create this situation and we certainly do not have the resources to change it.

- At both the state and university levels, the relative dispersion of funds has increased over time. Dispersion of NSF research funds among the states is about the same as NIH. NSF is more dispersed than DOD, but less dispersed than USDA, which funds land-grant institutions via formula. Among the approximately 300 universities that conduct sponsored research, NSF has the most dispersed series of research funding awards.

Peter W. House

Attachments

NATIONAL SCIENCE FOUNDATION
OFFICE OF THE ASSISTANT DIRECTOR FOR SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS
WASHINGTON, D.C. 20550

DATE: October 9, 1991

TO: Assistant to the Director, O/D

VIA: Acting Assistant Director, STIA

FROM: Senior Staff Associate, OAD/STIA

SUBJECT: September 27th Letter from Rep. Howard Wolpe

In response to your October 2, 1991, memo regarding the September 27, 1991 letter from Rep. Howard Wolpe, attached is material provided as background for the NSF Director and Deputy Director in connection with Session III of the Meeting of the Heads of Research Councils of the G-7 nations in Ottawa, Canada, June 27-28, 1991. This material consists of:

1. "III. Executive Summary: Projections of the Supply and Demand for S&E's in the U.S. -- All Degree Levels and Ph.D.'s" [One-page summary prepared by L. Lederman.]

2. "Demography and NS&E's: The Argument in Brief" [one-page summary]
"Demographic Factors and the Production of Degrees" [one-page summary]
"Fig. 1, Historical and Projected 22-year-olds in the U.S."
"Fig. 2, Past and Projected Ethnic Composition of U.S. 22-year-olds"
"Fig. 3, U.S. Bachelors Degree Participation"
[These documents were provided by PRA.]

3. "Projected Industry S/E Demand" [1 1/2-page summary]

   "Table B-18: Total and scientist/engineer employment by industry: 1980, 1988, and projected to 2000" [4-page table]

   "DRI/NSF Model of the Science-Engineering Ph.D. Labor Market: Projections and Properties" [cover page, one-page summary, one-page Exhibit 1]
   [These documents were provided by SRS.]

Leonard L. Lederman

III. EXECUTIVE SUMMARY: PROJECTIONS OF THE SUPPLY AND DEMAND FOR S&E'S IN THE U.S.--ALL DEGREE LEVELS AND PH.D.'S

The projection of the supply and demand (S/D) of all scientists and engineers (S&E's) in the U.S. has been a perpetual source of controversy--especially in the last few years. The following summarize the various points of view and projections.

o [redacted] of the relevant age group and the declining percent of all students interested.

o They have also projected a "shortfall" of Ph.D. NS&Es based upon their projected decline in undergraduate degrees and the peaking of retirements.

o [redacted] Most forecasters say demand is likely to continue to grow but at slower pace than over the last decade or two. [redacted]

o [redacted] (a) the BLS occupational surveys and forecasts in combination with (b) the inter-industry matrix economic model forecasts of DRI a leading economic forecasting organization. Soon a supply model built by Prof. Robert Dauffenbach of Oklahoma State University will be available and integrated with (a) and (b). The resulting model is a complex multi-factor, multi-equation model that forecasts the number of S&E jobs--high, medium and low projections of demand for S&E's--at all degree levels by occupation and industry. It is PC mounted at SRS and can be used to see the effect of changing assumptions, scenarios, variables, weights and options (e.g. reduced defense expenditures).

o These SRS projections contain market feedback and other adjustments (e.g. field switching, salary adjustments, students reaction to job and salary offers) and most importantly they deal with the current stocks as well as the flow of new graduates.

o The current results of this work indicates that the next decade may see some spot shortages in certain S/E occupations/disciplines and industries, as in the past, but there are unlikely to be an overall S/D imbalance.

o SRS has also completed work on a model of Ph.D. S/D using similar procedures. The results indicate the greater likelihood of shortages especially in academia. However there are a number of adjustment mechanism that could take care of most problems. This was done by changing scenarios and sensitivity testing. The possible adjustment mechanisms that have been discussed/written about in the community include stretching out the retirement peaking, hiring 2 out of 6 post-docs into tenure track positions rather than the usual 1 out of 6, increasing teaching loads from the 7-8 hours/wk. average to 8 to 9, etc.

o A number of other S&E S/D forecasts have been made but generally speaking the methods used and the results fall in the range of the two summarized above. (See back-up material included at the end of chart section for a more detailed summary and actual charts/tables summarizing results.)

NATIONAL SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

August 5, 1991

DIVISION OF POLICY
RESEARCH AND ANALYSIS

Mr. Richard E. Stephens, Associate Director
Office of University and Science Education
Office of Energy Research
U.S. Department of Energy, ER-80
1000 Independence Avenue, S. W.
Washington, D. C. 20585

Dear Mr. Stephens:

Recently, you requested my comments on a report prepared by Sandia National Laboratories, "Perspectives on Education in America." PRA staff analysts have [redacted] recommend that it be more fully vetted before it is disseminated to a [redacted]

The issues raised in the Sandia report are important. It is therefore equally important that the analysis be sound, since acceptance of this report could have a major impact on the Federal Government's education program. PRA analysts find that the report rests on a [redacted] analysis, which does not reflect a full understanding of relevant reported [redacted] does not constitute a cohesive analysis; and that the conclusions presented are [redacted] supported. We urge you to consider these limitations before relying on its conclusions. A more complete review of its contents is warranted.

PRA analysts stand ready to work with your staff and the staff of Sandia Laboratories in this matter. Detailed comments are enclosed.

Sincerely,

Peter W. House
Director

REC'D O/D ---

7 AUG 91 9:26

Enclosure

cc: Dr. Massey
Dr. Bernthal
Dr. Harris
Dr. Williams
Mr. Ubois
Dr. Bye

Preliminary Technical Review of Draft of *Perspectives on Education in America* by Sandia National Laboratory

A preliminary review of the subject briefing document has been completed by several of our staff. We have observed several major flaws of the following types:

- Lack of understanding of the data series used.
- Unresolved conflicting interpretations.
- Opinions interspersed with facts.

We suggest that much further effort is required before *Perspectives on Education in America* can be suited for public release. Following are examples of the dozens of flaws detected in our preliminary review:

Dropout-Retention Rates

By Race/Ethnicity: The Sandia document presents dropouts by race/ethnicity without reference to size of cohort or other important socioeconomic variables. Using data from the NCES longitudinal surveys, it is concluded that "most dropouts do not have 'at risk' identifiers and do not fit the stereotypical image of a dropout." The first phrase is partially true, because Whites still dominate the population, but it ignores the higher rate for minority dropouts. But the analysis ignores the two most important determinants of educational achievement, *viz.*, family income and parental education, which were available in the NCES longitudinal data. When these two factors are considered, race and ethnicity almost disappear as achievement determinants. In other words, among children whose parents have adequate income and college education, minority educational achievement in high school and college is essentially the same as for white children. Later, the analysis lists six characteristics of dropouts that basically reflect a single point: the majority of dropouts are white. Conspicuously absent from the list are parents' income and education.

By Family Income: When the analysis does consider family income as a factor in high school dropout rates, it is unconnected with race/ethnicity. The Sandia report presents data for the State of New Mexico which purports to show no correlation between high school dropouts and income. While providing some information about the distribution of students who leave New Mexico schools, this part of the analysis suffers from several important limitations.

The data show school reports of dropouts, as compiled by the state education authorities. However, they rely upon the reports received from school districts which typically are unable to distinguish between students who leave school and those who move out of the school district. The school officials rely upon the receiving district or school to contact them, failing which the students are classified as "dropouts".

The analysis suffers from the well known "ecological fallacy" which occurs when data referring to individual activity, such as children who leave school or children living in poverty households, are correlated after they have been aggregated. The problem is that this type of analysis is not sensitive to differences in the dropout rates among economic groups. While the chart seems to show little relationship between dropout rates and poverty rates across school districts, there may still be important differences within school districts. Because dropping out and poverty are characteristics of children and families rather than school districts, it is not appropriate to rely on the aggregated correlations. Determining the true correlation between family income and school attendance requires correlation at the individual level, as has been done in the extant literature on the subject.

Another problem relates to the size of school districts shown in the chart. The city school districts have a large number of students, while some rural districts may have only a limited number of students. But each is shown as a single data point. This means that the variation within large school districts is not shown.

College and University Data

The Sandia analysis of college degrees and employment falls into a taxonomy trap. Employment taxonomies and college degree taxonomies are based on very different criteria. The analysis compares the number of science and engineering bachelors' degrees with the number of those newly employed in job categories classified as "science/engineering," discovers that 40% are in other types of jobs, and concludes from this that the U.S. is overproducing NS&E graduates by about 40%. This interpretation ignores those graduates who stay out of the labor market, and that the baccalaureate is not a terminal degree; some will pursue graduate degrees. More fundamentally, it rests on the faulty assumption that any job category not classed as science/engineering has no need for such skills. But people with bachelors' degrees in science/engineering have for decades taken jobs in teaching, marketing, management, and the like, i.e., such "overproduction" has been going on for a very long time. No attempt is made to explain why NS&E graduates continue to command large salary premiums over non-technical degree recipients, nor why scientists and engineers have an unemployment rate less than half that of other occupations.

Choice of Degree Fields

The Sandia grouping of technical degree fields ignores the well documented complementarity among the natural sciences and engineering fields by omitting the life sciences. This decision leads to erroneous conclusions. The large increases in engineering and in computer sciences then are said to have occurred at no cost except for a decline in mathematics which "can be attributed to the increases in computer science degrees." In fact, the engineering surge was accompanied by a complementary decline in life science degrees, and the computer science growth was accompanied by simultaneous growth in mathematics degrees. The biggest gains in computer science degrees occurred in colleges that were producing relatively small numbers of mathematics degree in the first place. It is worth noting that the share of total bachelors' degrees awarded in natural sciences and engineering fields is in decline, due largely to a drop in the number of computer science degrees.

Changing Demographics

The Sandia report uses inappropriate variables in this discussion. It emphasizes ethnic shares of the **total** population rather than the changes in younger cohorts. Ethnic mix changes by age (especially younger ages) are the important factors in the education debate. Race and ethnic data is confusing because Hispanics are also Whites or Blacks. Thus, careful manipulation of data series is necessary in extrapolations to avoid double counting. This issue has not been addressed in the Sandia report, making it difficult to interpret their projections.

In this connection, a point made by the Sandia group, but not fully developed, is important to understand. The low graduation rate of Hispanics is in large measure driven by heavy immigration of young Hispanics into the U.S., many of whom never really "drop into" the education system. These new immigrants affect the Hispanic drop-out statistics, which showed no improvement for Hispanic males in high school graduation rates over the last 15 years (47% in 1989), and only modest gains for Hispanic females (40% in 1989).

Student Performance on Standardized Tests

The analysis examines SAT and NAEP test score trends. The SAT data have been adjusted to correct for a changing mix of test takers in order to track the achievement of students of a given type. The findings generally agree with findings in the literature. The Sandia NAEP analysis is deficient in several respects, however. It focuses on performance at the most basic levels on the NAEP tests (equivalent to "getting by," or "C" level work), pays scant attention to higher performance levels, and concludes: "Although the gains have been modest at best, the national data on student performance does (*sic*) not indicate a decline in any area." The issue of the present or future adequacy of this level of performance is not addressed. A major uncited report by ETS, source of the NAEP data, reaches very different conclusions. Analysis of reading and mathematics scores shows some improvement since the mid-1970s among 9-year-olds, almost no improvement among 13-year-olds and a slight worsening among 17-year-olds. More importantly, the results indicate that only very low proportions of students are able to demonstrate top achievement for their age group, and the fraction drops from 1 out of 5 or 6 at age 9 (depending on subject matter) to 1 out of 16 to 20 at age 17. The ETS Report further indicates that family income and parents' education are extremely powerful predictors of how students perform on these tests.

Definition of Demographic Groups

The discussion of the "white" population as a percentage of the total population is confused and contradictory. The analysis states that "whites make up over 80% of the U.S. population. This will continue throughout the 21st century." Elsewhere it asserts that at the end of this period "whites will still make up 70 to 75% of the population." This appears to be the result of misreading Census data. The Bureau of the Census asks respondents to identify their race and, separately, their ethnicity, which yield a composite classification (e.g., Black non-Hispanic, White non-Hispanic, Hispanic). However, in many of the population series, Hispanics are included with either Whites or Blacks. Since at least 90% of ethnic Hispanics are White, the White non-Hispanic population is currently less than 80% of the total, and is projected to be considerably less than 80%.

Appropriateness of Age Cohorts

For the discussion of education issues, these total population numbers are poor indicators. A crisper picture emerges if one focuses on the appropriate age groups. For example, among 17-year-olds, Blacks, Hispanics and Native Americans were about 22% of the total in 1980, will reach at least 28% by the year 2000 and will be above 30% in the year 2010. Beyond that point, estimates become increasingly speculative. These numbers are considerably different from the shares among the population at large.

New Mexico and the U.S.

The report states that the New Mexico dropout situation is quite different from that of the Nation as a whole. (We have commented above on some methodological flaws in this part of the analysis.) This statement appears to be correct in the sense that the shares of different groups are quite different, reflecting overall population differences. But it is misleading in another important sense, that of dropout <u>rates</u> for particular groups. A table of numbers that compares New Mexico and the U.S. is constructed so that the only racial category for which data can be compared is "white." Here the NM number is virtually the same (.88) as the U.S. number (.90). Data for Blacks, Hispanics, and Native Americans are shown for <u>either</u> the U.S. <u>or</u> New Mexico but not both.

An Upper Limit for Graduation Rate

The analysis asserts that the U.S. has reached an upper bound for an attainable graduation rate. The data suggest that this is not so. The high school graduation rate for males aged 18-24 has averaged 79% for the past 15 years and has shown no long-term improvement. Over the same period, the female graduation rate for this age cohort rose from 82% to 84% by the mid 1980s and has since declined to 83%. As a conservative target, approximating the female graduation rate seems reasonable.

Propensity to Earn Baccalaureate Degrees

It is asserted that the percentage of students earning bachelors' degrees is increasing. However, a comparison of the degree earning experiences of the high school classes of 1972 and 1980 elucidates this trend. Both classes were studied using national probability samples that were repeatedly re-surveyed. These data indicate that 23.3% of the 1972 high school seniors, and 23.7% of the 1980 seniors earned bachelors' degrees over the next 6 years. In one sense, the performance of the 1980 high school class was worse, because greater percentages of these seniors attended some college (i.e., their graduation <u>rate</u> 6 years after entering college was lower). Comparing these two classes, the male attainment rate was identical, the female rate rose by 0.9 percentage point, the Black rate fell by 3.6 percentage points (to 14%) and the Hispanic rate rose slightly (to 11%).

Contradictory Data and Findings

The report contains numerous inconsistent statements. For instance, it states that a) we are over-producing highly educated youth; b) we are producing slightly fewer than labor market skills require; c) we are producing just the right number, and d) skills requirements cannot be projected more than two years out. No attempt is made to mesh these findings with the assertion of a vast overproduction of technically trained personnel. Similarly, we are told that the average performance of U.S. students on international standardized tests remains poor, relative to other industrial and developing nations. But relative to other industrialized countries, U.S. technical and non-technical baccalaureate completion rates are said to be unsurpassed at both undergraduate and graduate levels, and the U.S. is said to compare favorably on workforce and general population measures. How these apparently contradictory findings fit together is not explored.

MEMORANDUM

Date: September 12, 1991

From: Rolf Piekarz

To: The Record

Subject: Current Estimates and Projections of the Market for Engineers

The theme of the September 11-12 meeting of the Engineering Manpower Commission of the American Association of Engineering Societies is "Engineers in America's Future: Shortage or Surplus? On Which Projection are You Betting Your Future?" The topic of the inaugural session of this meeting was entitled, "Statistical Background: Current Estimates and Projections." This session had four panelists. Two presented technical discussions about aspects of estimating and projecting the supply and demand. The other two panelists presented the position that there is an impending shortage of engineers.

Presenting the case for a shortage of engineers (and also of natural scientists) were Susan Kemnitzer, Deputy Director, Division of Engineering Infrastructure Development, National Science Foundation and Malcolm Cohen, Project Director, Institute of Labor and Industrial Relations, University of Michigan at Ann Arbor. Sue Kemnitzer's position was based on evidence she had gathered during her tour as executive secretary to the Task Force for Women, Minorities and the Handicapped in Science and Engineering. Malcolm Cohen's position rests on findings from a study produced for the Department of Labor, using their labor market data for the 1973-1987 period and their projections for the economy for the 1988-2000 period.

The technical presentations were by Thomas Amirault, Labor Economist, Bureau of Labor Statistics, Department of Labor (Janet Norwood heads BLS) and Myles Boylan, Policy Analyst, Division of Policy Research and Analysis, NSF. Mr. Amirault described the models used to estimate the forecasts of labor demand for various occupational categories. He indicated that, in addition to model estimates, BLS labor demand forecasts contain a substantial input of judgment from the BLS staff. Dr. Boylan described the procedures and data used by PRA to obtain the findings in the various papers by the Division on the shortfall for natural scientists and engineers. He discussed how PRA had examined the potential effects of conditions such as starting salaries, freshman intentions, and emerging disciplines on the number of new degrees in natural sciences and engineering.

After the presentations, the moderator, Betty Vetter, asked the audience to submit questions to the panel. She distributed them among the appropriate panelists. Of the ten questions submitted to

Myles Boylan, only one specifically referred to the PRA estimate of the shortfall. All the others were technical questions about the data and estimating approach used by PRA.

MEMORANDUM

DATE: September 18, 1991

TO: Director, NSF

VIA: Acting Assistant Director, STIA Sept. 18

FROM: Director, Division of Policy Research and Analysis

SUBJECT: Wrap-up by Alan Fechter of September 11-12 American Association of Engineering Societies (AAES) Conference, "Engineers in America's Future: Shortage or Surplus?"

We have listened to the tape of Alan Fechter's remarks about findings and conclusions of the participants at the AAES Conference. Attached is an outline of what he said about the production of NS&E graduates by U.S. colleges and universities.

Peter W. House

Attachment

cc: Dr. Bernthal
Dr. Harris
Ms. MacFarlane
Dr. Cehelsky
Mr. Widder

MEMORANDUM

DATE: September 18, 1991

TO: The Record

FROM: Rolf Piekarz

SUBJECT: Wrap-up by Alan Fechter of September 11-12 American Association of Engineering Societies Conference, "Engineers in America's Future: Shortage or Surplus?"

In his overview, Alan Fechter observes that there exists a surprising consensus among the conference panelists about the issue of shortage versus surplus. Overall, Fechter remarks that he heard a consensus on four issues:

- It is hard to estimate a shortage of scientists and engineers.
- There is a strong sense that no current crisis exists.
- Many leading analysts and policy officials express a strong concern about the future supply of natural scientists and engineers.
- Some concern exists about recent college graduates who are disappointed about current job prospects.

Fechter identifies at least a couple of good reasons why it is difficult to estimate shortage:

- Different metrics are used to measure supply (i.e., field of science) and demand (i.e., occupational category).
- We know little about the dynamics of the market for natural scientists and engineers.

As to the absence of a current crisis, Fechter notes three contributing factors:

- Defense R&D is declining;
- An increasing amount of R&D is being sourced off-shore; and
- The U.S. is experiencing slow economic growth.

Fechter presents the consensus position that these conditions have depressed growth of demand for new college graduates in NS&E and have disappointed expectations of new entrants. He points out that this situation has not generated a substantial increase in unemployment; it is just that new entrants have to take less desirable jobs than they expected.

For the longer term future, Fechter observes that the participants expressed concerns about the quantity and quality of natural science and engineering graduates.

On quantity, concern was expressed about

- a decline in the number of college-age cohorts and the increasing proportion of these cohorts represented by minorities and women; and

- substantial increase in retirements of NS&Es in the near future.

On quality, Fechter argues that it is important to try to increase the interest and competence of students in NS&E, especially among minorities and women.

Fechter concludes, with a personal observation, that the discussion about shortage or adequacy of NS&E personnel should not revolve around clearing the market but around issues of how market equilibrium is to be achieved. In this context, he states that we can't think about a single number but must look at various indicators and scenarios.

Memorandum

Date: October 1, 1991

To: Peter House, DD, PRA

From: Myles Boylan, Policy Analyst, PRA

Subject: "Bromley Scoffs at Warnings of R&D Manpower Shortage", Science & Government Report (October 1, 1991).

This article is a condensed version of Bromley's after lunch speech at the Engineering Manpower Commission's Conference "Engineers in America's Future: Shortage or Surplus" on September 11 in which I participated. I found this synopsis to be accurate. I recommend to your attention the following points:

Editor/Publisher Greenberg needles Bromley for his "remarkable turnabout in relatively short time." (p2)

Bromley still acknowledges that demographic trends and college freshmen "intentions" data "would seem to indicate that this country faces rather severe shortages of scientists and engineers in the near future." (p2)

But Bromley believes that caution is the prudent course of action because "Labor markets in this country are remarkably flexible. Particularly in engineering..." (p2) Unfortunately he does not take the next step in recognizing that this flexibility in the production of new degrees was much easier during periods of rapid growth in bachelors degrees, a period now in our past.

Bromley's skepticism is buttressed by a December 1990 Report prepared by Larry Leslie and Ronald Oaxaca from the University of Arizona under and NSF/SRS grant titled "Scientist and Engineer Supply and Demand". Bromley's synopsis of this paper was "none of the models of interest to policymakers had much validity beyond one year. By the end of two years, the model predictions were almost worthless." This statement unfortunately was not identified by either Bromley or Greenberg as relating to a highly specialized set of predictions made by NCES (U.S. Dept. of Education) using very simple single equation models of future degree production during 1977-87. These models are not adequate representations of supply-demand models.

However, Bromley later stated that "in these cases of inaccuracy, it is the demand number that turn out to be wrong, supply numbers are relatively easy to obtain from the educational pipeline and relatively reliable". I think we should take this comment as a compliment on our analysis, since this has been exactly our approach for the last 5 years, and because we have stated in many written versions of our analysis that forecasting demand for new bachelors degrees in S&E fields is impossibly complex.

It is encouraging that Greenberg ends this article by stating: "The evidence in these matters is murky, neither fully supportive of the shortage school, nor conclusive in behalf of the new skeptics. It should be noted that Bromley is merely arguing that the warnings of shortage have proven wrong in the past. He has not dismembered the latest round of warnings." (p3).

RE: ITEM 1

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

DATE	INITIAL & SURNAME	ORG. SYM

MEMORANDUM

DATE: November 26, 1991

TO: AAD/STIA

FROM: Kenneth M. Brown

SUBJECT: SRS activities related to the market for scientists and engineers

Modeling the labor market for scientists and engineers is only a tangential activity in SRS. Here are the two examples:

Science and Engineering Indicators. Chapter 3, "Science and Engineering Workforce," of the edition in progress presents an outlook for S&E employment (see attachment). This analysis is based on a computerized model developed by Data Resources/McGraw-Hill, a private economic forecasting firm. The actual projections were developed under a grant to Prof. Robert Dauffenbach of Oklahoma University.

In my view, this treatment of the projections is careful [illegible] moderate. A range of possibilities is presented. The source of the projections is clearly identified, and there is no suggestion that NSF stands behind the numbers. Indeed, the discussion focuses on the dynamics of the labor market, rather than on the projections themselves.

Future work under consideration. We are developing a statement of work for an RFP that would provide enhancements to modeling work sponsored by SRS in years past. While SRS will benefit from the enhancements, nearly all of the cost would be borne by two federal agencies that want specific results for their own use:

-- The Nuclear Regulatory Commission wants projections and simulations that will help them manage their own recruitment and retention of scientists and engineers.

-- The National Center for Educational Statistics wants to project higher education enrollment by race and ethnicity, and by other characteristics. (This, we hope, will be useful to us for the 1993 edition of Women and Minorities in Science and Engineering.)

Probably more important than the projections is the help this work will give researchers and policymakers in understanding how labor markets work (e.g., how do economic factors, like the defense-spending slowdown, affect the demand for engineers). The work is in line with recent BBS grants for related economic research on S&E labor markets.

We are designing the RFP to produce useful results for NSF, NCES, and NRC, but we are aware of possible pitfalls. [redacted]

Attachment of xerox from SI

cc: J. Fenstermacher
[redacted]
C. Shettle

bcc:KBROWN:trg:634-4027:11-26-91
/SRS Chron

cent. Life scientists and engineers in all subfields registered above average growth rates—3.5 percent and almost 4 percent annually. Slower than average growth was recorded by physical and mathematical scientists, who increased by only 0.9 and 1.3 percent per year, respectively. These differing growth rates changed the field distribution of doctoral scientists and engineers over the period. For example, the proportion of physical scientists declined from about 17 to 13 percent, and the proportion of engineers rose from 10 to 11 percent.

After experiencing a slowdown in growth in the mid-eighties, doctoral scientist employment in academia has rebounded in recent years. Employment of Ph.D.-holding scientists increased at an average annual rate of 2.8 percent between 1987 and 1989, up substantially from an annual growth of 1.3 percent for the previous 2-year period. Opposite patterns were experienced by doctoral engineers, whose employment increased by 4.6 percent annually over the 1985-87 period and then dropped to fewer than 3 percent per year over the next 2-year period.

Industry. Since the late seventies, the sectoral distribution of doctoral scientists and engineers has shifted toward industry, increasing at average annual rates of 6.5 and 5.2 percent, respectively. By 1989, 28 percent of all Ph.D.-holding scientists and 56 percent of all doctoral engineers worked in industry. The computer sciences, psychology, and the social sciences were the fastest growing science fields for doctorate-holders employed in industry; aeronautical/astronautical, civil, and electrical/electronic were the fastest growing engineering subfields.

Overall, industrial employment of S&E doctorate-holders has slowed since the early eighties. Between 1983 and 1989, the employment of doctoral scientists in industry increased at an average rate of less than 4.6 percent annually; doctoral engineering employment rose 3.3 percent per year. These declining growth rates reflect several factors, including

- A [illegible]er demand by academia for S&E doctorate-hol[illegible]
- A shortage of doctoral personnel in such high-demand S&E fields as the computer sciences and certain engineering specialties; and
- The relatively strong growth in development activities, which, as compared to basic and applied research, are generally carried out by less highly trained personnel (S'IS 1988b, p. 22).

A few S&E fields/subfields did not experience a declining growth rate in the latter half of the 1977-89 period: These were the physical sciences and mechanical and civil engineering.

Employment of Women and Minorities

Women. Women continue to account for an increasing share of the employed Ph.D.-holding scientists and engineers. Their representation grew to 17.2 percent in 1989 compared to 9.7 percent in 1977. The fields with the greatest relative growth of women doctorate-holders were the computer sciences—which increased employment of doctoral women from fewer than 250 in 1977 to over 2,300 in 1989—and engineering—which increased employment from fewer than 300 to over 2,300 during the same period. Despite this rapid growth, only about 6 percent of doctoral women were either computer specialists or engineers in 1989. (See figure 3-15.) The life sciences, social sciences, and psychology together accounted for over 80 percent of the period's increase in the employment of doctoral women. Overall, the field distribution of women with science doctorates did not change greatly over the 1977-89 period. Women were, however, somewhat more likely to be psychological scientists or computer specialists and less likely to be mathematical or physical scientists in 1989 than in 1977.

Minorities. Over the 1977-89 period, the numbers of employed black and Asian S&E doctorate-holders rose at average annual rates of 8.4 and 8.0 percent, respectively. These rates were more than twice the 3.7-percent rate for whites. More recently (1987-89), S&E doctorate growth has slowed; black and Asian Ph.D.-holders increased at average rates of 6.1 and 6.3 percent per year, respectively, while the number of employed white doctorate-holders grew at about 3.2 percent annually.

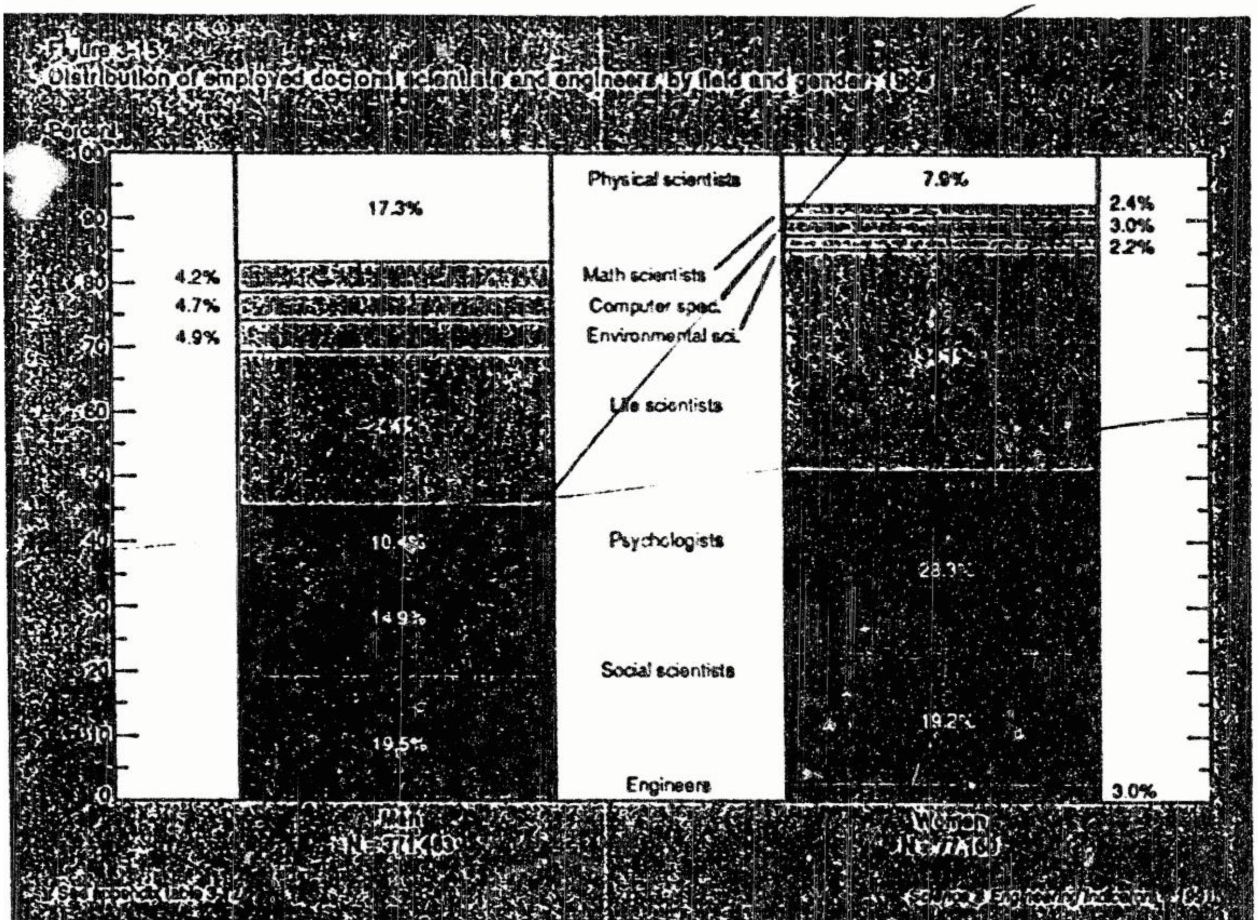
Despite their rapid employment growth, blacks accounted for only about 1.6 percent (7,200) of all employed doctoral scientists and engineers in 1989. (See figure 3-16.) This proportion represented a slight increase over 1977, when blacks accounted for only 1.0 percent of employed doctoral scientists and engineers. On the other hand, the more than 41,000 employed Asians with S&E Ph.D. degrees represented about 9.2 percent of the total in 1989, up significantly from 5.7 percent in 1977.

Supply and Demand Outlook for S&E Personnel[12]

The 1990s should be a period of relative stability in S&E labor markets, particularly as compared with the defense buildup of the early to mid-1980s when many S&E fields experienced temporary shortages.[13] This con-

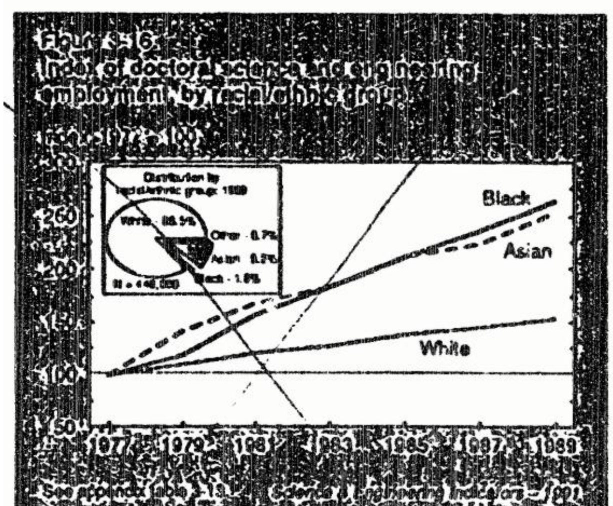
[12] This section presents findings of a special analysis undertaken by the National Science Foundation (NSF). The objectives of the study are twofold: (1) to project S&E personnel requirements during the 11-year period 1990-2000 and (2) to assess the adequacy of the projected supply of such personnel available to meet those requirements. Employment projections for the study were generated by NSF's PC occupations modeling system, developed by Data Resources, Inc./McGraw-Hill, a private economic forecasting firm. The supply projections, perhaps the distinctive feature of this analysis, were based on a model that incorporates all major sources of response to changes in demand. Developed under grant to Dr. Robert Dauffenbach (Oklahoma University), these projections are intended to identify potential problems within the S&E labor market, as well as to assist in understanding the dynamics and flexibility of the S&E labor supply.

[13] The term "relative stability" indicates an overall balance between total supply and demand for scientists and engineers. It does not mean that supply and demand for each S&E field will be in perfect equilibrium throughout the decade. As has been the case in the past, spot shortages and surpluses will continue to occur across various S&E fields in response to supply/demand fluctuations.



clusion has been reached after a careful examination of

- Various demand simulations to determine how alternative national economic growth patterns might affect S&E employment, and
- Supply side simulations to test the ability of the supply system to respond to these various demand scenarios.



The supply and demand models used to produce these simulations try systematically to account for the many institutional features, individual behavior patterns, demographic trends, and economic forces that govern S&E labor markets (Leslie and Oaxaca 1991). Results and features of these models are provided in this section.

Operations of the S&E Labor Market

Because the performance of the U.S. economy is a major influence on S&E employment, it is important to understand the fundamental operations of the economy in generating jobs for scientists and engineers (see "S&E Employment: Demand Side," p. xx), and in filling those jobs through education and training institutions (see "S&E Employment: Supply Side," p. xx). The models upon which the following results are based attempt to capture these fundamental operations systematically. In this manner, alternative scenarios about the future and the ability of the supply system to meet such contingencies can be examined and assessed.

A variety of demand scenarios can be envisioned. For example, one scenario might involve high overall growth in U.S. output, a shift toward services and away from manufactured goods, lower military hardware produc-

S&E Employment: Demand Side

From the demand perspective, employment of S&E personnel begins with final industry demand that is, the output of goods and services from the various agriculture, mining, manufacturing, and service industries that is available for purchase by households, businesses, government, and foreigners. Because industries buy raw materials, products in intermediate stages of production, and services from other industries, the total volume of production in a given industry exceeds the total available for final purchase. *Final demand* in the various industries thus needs to be translated into *total output* per industry.

Once total industry output is known, productivity ratios that is, output divided by labor input can be used to compute employment by industry. From there, it is a simple matter to translate the industrial employment into occupational employment. This translation is accomplished through use of the occupational employment distribution per industry the percentage of employees who are scientists and engineers, managers, clerical employees, blue collar, etc. Summing the resulting employment by occupation across industries yields total occupational demand. Thus, through such models, it is possible to translate alternative final demand patterns into estimates of total employment by occupation.

tion, and extensive defense and nondefense R&D. It is possible to imagine other scenarios that might involve slow overall growth of the U.S. economy, but with a shift in production of goods and services toward industries that rely heavily on S&E employment. Even though aggregate economic output would not change under such a scenario, S&E employment would expand. Many such scenarios could be developed and then tested relative to the ability of the supply system to respond.

Three adjustment mechanisms dominate supply responses in the present modeling framework: degree shares, employment retentions, and field mobility. In response to high levels of demand, degree shares (S&E degrees as a percentage of total degrees awarded) increase in the corresponding categories (Dauffenbach 1990). Also, retentions in S&E employment domains increase, which is to say that a high percentage of S&E graduates remain in S&E occupations rather than pursue alternative careers in marketing and management. In addition, workers with training in the shortage occupations become more concentrated in their respective fields of employment, and workers with training in related fields shift their employment to the occupations experiencing shortfalls. Final outcomes of the supply simulations show the leveling effects of the operations of the supply system. Both shortages and surpluses are lessened, exhibiting much more favorable balance than the initial changes in demand would indicate.

Projected Demand for S&E Personnel

As described above, projections are forecasts that are conditional upon a variety of assumptions that depict economic, institutional, and social conditions. The analysis in this section was therefore designed not to provide a single numeric estimate of future employment requirements, but instead to provide a well-defined range within which employment growth is likely to occur during the 1990-2000 period.

Three projection scenarios—a "low," a "mid," and a "high"—were analyzed with the demand model using alternative sets of assumptions designed to encompass likely economic performance during the simulation period 1990-2000.[14] (See text table 3-3 for a summary of these assumptions.) S&E employment changes vary substantially from 1990 to 2000 under the three alternative economic growth scenarios:

- *Low growth*—S&E employment is expected to expand by 13.6 percent;
- *Mid growth*—S&E employment is expected to expand by 20.6 percent; and
- *High growth*—S&E employment is expected to expand by 26.7 percent.

(See text table 3-4.)

Growth differs dramatically among the five major groups of S&E employment: engineers, math and computer specialists, biological scientists, physical scientists, and social scientists. As shown in text table 3-4, the principal beneficiaries of growth in the 1990s are expected to be math and computer specialists and engineers. Under the low-growth scenario, demand is particularly weak for physical, biological, and social scientists. Under all scenarios, growth is concentrated among the engineering and math and computer specialties. This degree of concentration raises a concern as to the ability of the supply system to adjust to meet this demand.

Supply Side Responses

There are many ways in which the supply system can adjust to meet this contingency of concentrated growth, including the following:

[14]The economic assumptions used in the three projection scenarios (low, mid, and high) were provided by Data Resources, Inc./McGraw-Hill. The scenarios were run in the summer of 1991. Based on these assumptions, NSF's PC occupations modeling system generated estimates of projected total employment by sector. The occupational structure used by the Bureau of Labor Statistics was applied to the total employment projections.

The scenarios are *not* predictions; consequently, departures from the assumptions on which the scenarios are based may alter future outcomes significantly.

- Students presently enrolled can shift to high-growth majors.
- Recent graduates with related degrees can seek employment in high-growth fields.
- Experienced workers can seek retraining and become occupationally mobile into such jobs.
- Experienced workers with training in high-growth fields who are pursuing non-S&E careers can return to S&E employment.
- Those working in high-growth fields can extend their careers in those areas.
- Immigrants can make up some of the shortfall in high-growth areas.
- Later retirement could offset high demand.

The supply model needs to capture these various facets of flexibility in system operations. However, the amount of flexibility the supply model exhibits must be based on historical magnitudes (Collins 1988).

Supply model simulations were run on each of the three demand scenarios.[19] Overall, the low-growth supply simulations show about a 4.0-percent overall surplus by 2000—a particularly slow growth scenario. (See figure 3-17.) Below average surpluses are shown for math and computer specialists and physical scientists, while surpluses for the other occupational groups are slightly above average.

The mid-growth scenario indicates approximate balance—only about a 0.5-percent overall surplus. The balancing effects of supply system operations leave only a small percentage difference between the field of highest comparative shortage and highest comparative surplus.

The high-growth scenario, which yields an overall 26.7-percent growth in demand in the 1990s, results in an

[19] The S&E supply model used to produce these estimates was developed for NSF by Dr. Robert Dauffenbach under an NSF grant to Oklahoma State University. The current model builds upon an earlier model application (see Dauffenbach and Fiorito 1983).

Text table 3-3.
Summary statistics for macroeconomic scenarios: 1990-2000

Indicator	Low	Mid	High
	Average annual real growth		
	Percent		
GNP	1.7	2.2	2.7
Consumption	1.2	1.7	2.0
Business fixed investment	2.3	3.6	5.1
Exports	[illegible]	6.7	[illegible]
Imports	[illegible]	4.0	4.0
	Average annual growth		
	Percent		
Labor force	0.7	1.2	1.6
Productivity	0.9	1.3	1.5
Industrial production	1.0	2.5	3.1
	Average level		
	[illegible]		
	Percent		
Inflation (GNP deflator)	[illegible]	3.6	3.1
Unemployment	6.2	6.0	5.9

NOTES: Growth rates for the projection period are compound annual growth rates calculated between the years 1990 and 2000. Level variables are averages for the years 1991 to 2000 (e.g., inflation and unemployment).

SOURCES: National Science Foundation and Data Resources Inc./McGraw-Hill, unpublished tabulations.

Science & Engineering Indicators – 1991

S&E Employment: Supply Side

On the supply front, there are many factors that must be considered. A large amount of attention is typically paid to the production of S&E college degrees at both the baccalaureate and graduate levels. Underlying demographic trends of the college-age group, their rates and trends in college attendance, their willingness to pursue S&E degrees, and their willingness to work in S&E jobs once they graduate must also be examined. Recent college graduates represent a flow of new S&E personnel into the supply system. (See "Demographic Trends: Recent S&E Graduates," p. 22.)

These flows of newly trained personnel are much smaller than the stocks of employed people in various S&E occupations. (See NSB 1989, pp. 77-80, for an extensive discussion of S&E labor market stocks and flows.) The stocks of employed persons in S&E occupations, in turn, are smaller than the total number of S&E personnel in the workforce. Take, for example, engineers. In 1989, there were 67,200 bachelor's degrees awarded in engineering and about 1.6 million people employed in engineering jobs (not all of whom had engineering degrees). However, since World War II, the total number of engineering bachelor's degrees earned in the United States exceeds 2.0 million. A very large percentage of these graduates are still in the workforce today. Thus, as important as the flows of new S&E graduates are to the supply system, these numbers are small compared to the stocks of people employed in S&E occupations and the number in the labor force who have training in S&E fields. Consequently, small changes in the behavior of experienced workers can have dramatic supply consequences. Supply models must capture the behavior of experienced workers through analysis of the longevity of S&E careers. Supply models must also take into account the willingness and ability of S&E-trained personnel to work in occupations that do not exactly match their training (Dauffenbach 1990). This latter concept is known as field mobility.

Text table 3-4
Projected science and engineering job growth[illegible]

Occupational group	1990	2000 Low	2000 Mid	2000 High
Total scientists and engineers	[illegible]060	[illegible]476	3,689	3,87[illegible]
Percentage change		13.6	20.6	26.7
Engineers	1,555	1,740	1,877	1,990
Percentage change		11.7	20.5	27.[illegible]
Math and computer specialists	658	839	883	[illegible]31
Percentage change		27.5	[illegible]	[illegible]
Biological scientists	[illegible]	31[illegible]	327	339
Percentage change		[illegible]	[illegible]	[illegible]
Physical scientists	248	269	27[illegible]	28[illegible]
Percentage change		7.5	12.6	17.6
Social scientists	300	315	325	336
Percentage change		5[illegible]	[illegible]	12[illegible]

SOURCES: Bureau of Labor Statistics and National Science Foundation, unpublished tabulations.

Science & Engineering Indicators – 1991

overall shortage, but not a significant one. Overall, total supply equals 98.0 percent of total demand. There are only a few examples of detailed S&E occupations where the extent of the shortage exceeds 2.0 percentage points.

Unanswered Questions

The Questions. Despite modeling advances to assess S&E employment outlooks, uncertainty remains high on both sides of the supply/demand equation. The questions abounding on the *demand* side include the following:

- Will decreases in defense spending dramatically affect S&E labor markets?
- Will the threat of foreign competition drive U.S. manufacturers toward more R&D spending?[18]
- Will the generally slower growth prospects for the U.S. economy impinge on demand for S&E personnel (SRS 1988b)?
- Will the rebuilding of Eastern Europe lead to a surge in demand for capital goods that have sizable S&E components?
- Will Federal budget deficit problems lead to a slowing of Federal R&D spending?

As these questions show, the impacts of recent events do not lead in a consistent direction. Some lead to increases in demand; others, to decreases.

[18]This circumstance could have a negative impact on demand for S&E workers if companies increase their fractions of R&D outside of the United States (where the labor involved is largely foreign nationals).

On the *supply* side, too, there are many unanswered questions:

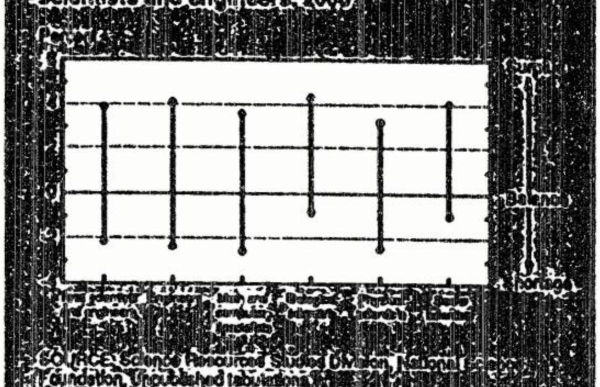
- Will the United States be able to continue its reliance on immigrants to fill Ph.D.-level jobs (Forrest 1990), or will rising international S&E demand begin to draw off this talent?
- Will the upheavals in Eastern Europe and the Soviet Union, coupled with relaxation in emigration rules, lead to a massive exodus of S&E workers to the Western world?
- Will smaller youth cohorts in the prime college attendance years begin to have a dramatic impact on S&E degrees?
- Will women and minorities, who now make up a larger proportion of the college-age pool, begin to pursue S&E educational opportunities in increasing numbers (SRS 1990a, p. 31)?
- As larger proportions of S&E workers enter the 55 years and older age group, will retirements begin to have a much more significant supply impact?
- What are the implications of extending mandatory retirement to age 70?

As with demand, uncertainties in supply also do not point in the same direction.

Answer Lies in Supply Flexibility. The supply system reveals a fairly high degree of flexibility in the face of uncertain demand shocks. It is not infinitely responsive, however. Other factors limit its flexibility:

- The adjustment mechanisms the supply system incorporates are not without costs in lost productivity; retraining expenses; and employer, industry, and occupational mobility.
- In the high-growth scenario, it may prove difficult for higher education to respond to the demand for degrees in fields experiencing relative shortages.

Figure 3-17
Estimated range of supply/demand differentials for scientists and engineers: 2000



SOURCE: Science Resources Studies Division, National Science Foundation, unpublished tabulations.

Science & Engineering Indicators – 1991

Moreover, since the more willing and sometimes more able are likely to be the first to engage in field mobility, the real and psychological costs of retraining and mobility will rise with each incremental need for change. It will prove increasingly costly to retrain personnel who are field-mobile to the areas of high demand.

As costly as such dislocations are, the supply system appears capable of adjusting to rather wide differentials in demand growth. The overall demand growth differential between the low and high scenarios is 11.5 percentage points (24.4-percent growth in the high-growth scenarios versus 12.9-percent growth in the low-growth scenario). Supply system operations reduce this differential to about half its former size: 1.4-percent shortage to 4.0-percent surplus, or a 5.4-percentage point differential. (That is, about half of the difference in demand between the high- and low-growth scenarios can be accommodated by adjustments in the supply system.)

Neither of these numbers represent a high degree of disequilibrium in the market for scientists and engineers. These demand scenarios and attendant supply processes can thus be said to exhibit relative *balance* for S&E labor markets in the 1990s. The possibility of spot shortages in certain S&E fields is not precluded, however. For example, the adjustment mechanisms in the supply system may be insufficient to meet the expected increase in demand for computer systems analysts.

Because of these many lingering uncertainties, S&E labor markets need to be followed closely and the scenarios and models improved continuously.

International Employment of Scientists and Engineers

A country's employment of scientists and engineers is a significant indicator of its level of effort in and relative national priority for science and technology. International comparisons are complicated by differences in countries' definitions of specific jobs and in methods of data collection and estimation. Still, international employment data provide insight into the relative strengths of the S&E workforces in the United States and other countries.

This section explores trends in international S&E employment, including employment sectors, primary activities, and employee characteristics in France, Italy, Japan, Sweden, the United Kingdom, the United States, and West Germany.[9] Also included is a brief discussion of trends in the emigration of foreign scientists and engineers to the United States. (See "Immigration," p. xx.)

International S&E Job Patterns

In the early to mid-1980s, the number of nonacademic scientists and engineers employed in the United States exceeded the combined total of those in France, Italy, Japan, the United Kingdom, and West Germany.[10] Examining the number of scientists and engineers as a proportion of each country's total labor force shows that the United States employed the highest percentage of scientists and engineers, followed closely by (in descending order) Japan, West Germany, the United Kingdom, and France. Italy employed the lowest proportion of scientists and engineers. (See figure O-7 in Overview.)

In the five countries compared here (France, Japan, the United Kingdom, the United States, and West Germany), the services sector is usually the most important employer of scientists, while most engineers are employed in the manufacturing sector. In the 1980s, the services sector was the largest employer of nonacademic scientists in all countries except West Germany; there, manufacturing industries employed the largest percentage of these scientists. (See figure 3-18.) The manufacturing sector was the largest employer of nonacademic engineers in all countries; it was particularly significant in the United States and the United Kingdom, where it employed half of the engineers. The services sector employed the next highest proportion of nonacademic engineers in all five countries.

By occupation, industrial/mechanical engineers constituted over half of the S&E manufacturing workforce in the United States (1988) and the United Kingdom (1981). The proportion of these engineers was also high in France (1987) and West Germany (1985), where they accounted for between 43 and 45 percent of all scientists and engineers employed in manufacturing.

The distribution of the Japanese S&E manufacturing workforce differed from that of the other countries. In Japan (1985), the largest proportion of its S&E manufac-

Immigration

Immigrant scientists and engineers are an important component of the S&E workforce in the United States. They represent a valuable resource to the Nation's economy.

In 1988, 11,000 scientists and engineers emigrated to the United States. Forty-five percent of these immigrants came from Asia, three times the number that came from Western Europe. By country, the largest numbers of immigrants came from India, Taiwan, the Philippines, and the United Kingdom; each of these countries accounted for more than 750 immigrants.

Almost three-quarters of the S&E immigrants to the United States were engineers. Only 11 percent of the new immigrants were in the natural sciences, 11 percent were mathematicians or computer specialists, and just 4 percent were social scientists.

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[9]Italy and Sweden are excluded from several discussion areas because of a lack of comparable data. West German data are for West Germany only and do not include data for the former East Germany.

[10]Academic S&E employment is excluded from this discussion because data are not available.

RE: ITEM 1

[596] From: ksandved at nsf12 12/23/91 9:27AM (592 bytes: 7 ln)
To: kbrown at nsf15
cc: jfenster at nsf5, gglaser at NOTE, phouse at nsf15, hwolff at nsf17
Subject: Supply and Demand
------------------------------ Message Contents ------------------------------

When we (I) alerted O/D to the piece on this subject in S&E Indicators, you will recall that I deliberately left out mention of the pending BLS agreement so as not to muddy the waters. While I think the ministorm over this issue may be behind us, it would seem prudent to alert O/D to the agreement as you get closer to signing on the dotted line.

RE: ITEM 1

DIVISION OF SCIENCE RESOURCES STUDIES
Telephone (202) 634-4300

FACSIMILE COVER SHEET

PLEASE DELIVER THE FOLLOWING PAGES TO:

NAME: Neal Rosenthal

LOCATION: BLS

FAX NO: 504-2324

FROM:

NAME: Keith Wilkinson

LOCATION: NSF/SRS

DATE TRANSMITTED: 12/31/91 TIME: 3:15

WE ARE TRANSMITTING 1 PAGES OF MATERIAL, INCLUDING THIS COVER SHEET. IF YOU DO NOT RECEIVE ALL 1 PAGES, PLEASE CALL US AS SOON AS POSSIBLE.

PHONE (202) 634- 4300 (Verification Number)
(202) 634-4683 (Fax Number)

Neal,

It doesn't look like we will be able fund a contract for this year. I will call next week to confirm.

Keith
Keith

[1175] From: ksandved at nsf12 2/26/92 8:44AM (678 bytes: 9 ln)
To: kbrown at nsf15
cc: ksandved
Subject: Supply and Demand
------------------------------ Message Contents ------------------------------

Thank you for calling to my attention an E-mail message that I sent you on December 23 of last year. It must have confused you no end. I believe it referred to a memo you had sent me summarizing SRS-supported studies of market conditions for S&E personnel, including a potential contract to be funded mostly by other agencies. The purpose of my message was to suggest you go slow on the RFP. It is a mystery to me how I came to garble that by referring to BLS. So much for one-way, careless communications. Sorry.

APPENDIX 4

NSF draft reports on the scarcity of scientists and engineers

THE SCIENCE AND ENGINEERING PIPELINE

NATIONAL SCIENCE FOUNDATION
Directorate for Scientific, Technological, and International Affairs
Division of Policy Research and Analysis

PRA Report 87-2
April 1987

PREFACE

This report summarizes issues relating to U.S. academic science and engineering personnel policy that have been examined by the National Science Foundation's Division of Policy Research and Analysis over the past year. It proceeds from an understanding that tuition and state funding provide the force for the flow of scientists and engineers through a pipeline from undergraduate education to professional employment in NS&E occupations. Nevertheless, the Federal Government is seen to have an important interest in science and engineering personnel resources for purposes of national defense and economic health.

This pipeline analysis is based on a long-term simulation of the supply of academic science and engineering personnel. Reduced numbers of full-time undergraduates in 4-year colleges and universities now indicate a decline in NS&E graduates in a future predicted to have greater NS&E demands. Public policy appears likely to play a role in redressing the predicted imbalance.

Issues addressed include the following:

- Historical trends of production of B.S. and Ph.D. degrees in natural sciences and engineering.
- Declining population of young adult citizens.
- Occupational mobility.
- Institutional origins of B.S. and Ph.D. degrees.
- Future supply and demand for natural scientists and engineers.
- Possible strategies to minimize shortages.

It is estimated that private sector response strategies will take too long to adjust to the situation, and the likely adjustments, such as reliance on recruitment of foreign professionals, may reduce the average quality of services provided by employed NS&E's. Public sector options should consider strategies other than raw increase in the production of NS&E's, for example (1) computers and other capital-intensive training and support equipment; (2) continuing education for employed NS&E's to facilitate movement into areas of urgent need, and; (3) development of programs for technicians and other support services to make the NS&E workplace more effective.

The report and supporting analyses are the collective work of the PRA staff. It has been reviewed by many senior professionals in the Foundation, and many of their comments have been considered. However, the report does not represent the official policy of the Foundation or PRA, nor the judgement of any particular staff analyst. Anyone wishing to comment on or acquire further information on the report should call PRA at 202-357-9689, or write to the Division of Policy Research and Analysis at Room 1233, 1800 G Street, NW, Washington, D.C., 20550.

The PRA staff includes the following individuals, in alphabetical order: Evan Berman, Carol Bochert, Myles Boylan, Carol Heffner, Madeleine Hymowitz, G. Patrick Johnson, Eugene Krug, Kathy Kushner, Rolf Lehming, Minnie Mills, Jean Pomeroy, Rolf Piekarz, Alan Rapoport, Roger Shull, John Sommer, Bernard Stein, Patricia Taylor, Eleanor Thomas, and Robert Webber.

Peter W. House, Director
Division of Policy Research and Analysis

THE NATURAL SCIENCE AND ENGINEERING PIPELINE

SUMMARY STATEMENTS

This paper, although written from the perspective of the National Science Foundation, is largely contextual. The issues considered are far beyond what the Foundation is able to influence alone, even though most of them are a part of NSF's mission.

This paper focused on natural scientists and engineers (NS&E's), rather than on the larger population of scientists and engineers. The difference is the population of social and behavioral scientists. These are excluded in the bulk of this paper because their link to the health of the economy is less direct, and because the production of new social and behavioral scientists has proven in the past to be considerably less constrained by population demographics than has the production of NS&E's.

The Federal Government is not a major source of support for the education of NS&E's. Most of the funding comes from tuition or state governments. Nevertheless, the education of scientists and engineers is considered a legitimate concern of the Federal Government because of the importance of science and engineering to national defense and economic health. Evidence from the past suggests that we are going to need more NS&E's in the years ahead, although it is difficult to be very precise.

The future supply of NS&E's can be addressed with somewhat more confidence. There are currently fewer full-time undergraduate students in 4-year colleges and universities from which to draw the next generation of NS&E's, and this pool will decline for another 10 years or so. The percentage of this student body electing to go into science and engineering at the baccalaureate level has been more or less constant for years. There is little indication that this pattern will change substantially in the future. Consequently, it can be expected that there will be a decrease in the production of new NS&E's for 10 years or so. These predictions suggest a growing supply-demand imbalance, i.e., a growing scarcity of NS&E's, assuming the need for NS&E's continues to grow as in past years.

None of the so-called "market" solutions to this imbalance appear able to address it without some fairly substantial negative effects on economic growth and possibly even national defense. Public policy appears to be likely to play an important role for these reasons.

INTRODUCTION

The educational system in the United States has always been hierarchical. Advanced degrees (master's or doctorate's) are acquired after the successful completion of a bachelor's degree, a baccalaureate follows the successful completion of secondary education and so forth. For this reason the progression (and attrition) of students from primary education through graduate programs is conceptualized (and referred to) as a pipeline. Because a minimum of some number of degree-holders in each specific field is considered necessary or desirable for the health of that discipline and, at times, even of the Nation, the number of students in NS&E fields at each stage of the pipeline is important and monitored carefully. When the number of students at some stage in this pipeline is deemed too low in a given field, as compared with an anticipated need for their services, policymakers can deploy strategies designed to increase this number. Broadly speaking, these strategies seek to increase the percentage of students at that stage majoring in the shortage field or to reduce student attrition up to that stage, thereby increasing both the total number of students and the number in the targeted field. The success of past strategies of these types is inconclusive. It appears that strategies designed to reduce the attrition of students from NS&E coursework are more realistically based than field-specific strategies, because the time needed to adjust for shortages in a given field is too long to ensure that a given policy response will be appropriate to future market conditions. Regardless of the success of past efforts, there have been repeated calls for action to stimulate interest in NS&E careers by the science and engineering community and other interest groups, and this process will continue without much regard to past efforts. For example, the Post World War II period has witnessed a succession of statements professing the belief that the U.S. needs more natural scientists and engineers. Several examples are:

o 1945:

"Scientific suicide faces America unless immediate and adequate steps are taken to train replacements for technical men going into the armed services." [Charles A. Thomas, Director, Monsanto Company Research Laboratories]

o 1962:

"[T]his country faces an impending shortage of engineers, mathematicians, and physical scientists who combine high ability with graduate education...The problem is that diverse requirements for the more highly trained engineers, mathematicians, and physical scientists are rapidly outstripping our capability to produce them..." [President John F. Kennedy, December 12, 1962]

o 1980:

"I am increasingly concerned whether our science and engineering education is adequate, both in quality and in numbers of graduates, for our long-term needs." [President Jimmy Carter, February 8, 1980]

Such statements seem to surface regularly regardless of the number of scientists and engineers actually entering or expected to enter NS&E labor markets, regardless of the immediate demand for NS&E manpower, and regardless of the policies or practices already being employed to attempt to influence the number in the future. Efforts to verify emerging shortages or growing scarcities of NS&E's have not been terribly successful. The more complex supply and demand manpower models used to project the future have suffered from the traditional problems of all such attempts to build relatively complex forecasting models; an incomplete understanding of what factors influence the supply of new scientists and engineers, almost no idea of the real demand for their services in terms of measurable output per person, and, most notably, inadequate data.

THE SITUATION TODAY

The Pipeline: A Cross-Sectional View

Available data do permit, however, a fairly complete description of the pipeline covering the attainment of undergraduate and advanced degrees, particularly in NS&E fields, and the flow of NS&E degree-holders into employment, both NS&E and non-NS&E employment (Figure 1).

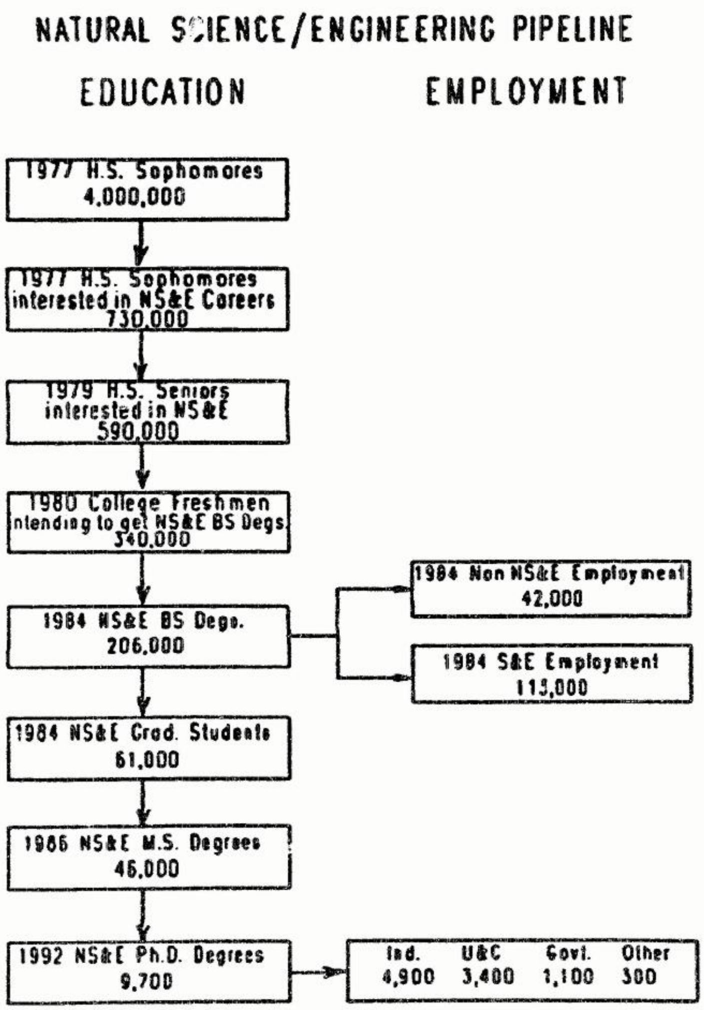

Figure 1

Starting with 4 million high school sophomores in 1977, only 5.1% (206,000) actually received a bachelor's degree in an NS&E field in 1984, and only about 5% of these (9,700) will go on to acquire a Ph.D. (most typically in 1992). Major attrition of student interest in NS&E careers has occurred by the high school sophomore stage of the pipeline. Only 18% of high school sophomores in the most recent "High School and Beyond" longitudinal Survey (conducted by Educational Testing Service of Princeton, New Jersey) indicated such interest. This figure, dropped to under 15% of this same 4 million population in the high school senior year (primarily due to dropouts), then plunged to 8.5% by the college freshman year. Of the 340,000 college freshmen that indicated that they intended to major in NS&E fields in 1980, 140,000 were in 2-year colleges. Most of the remaining undergraduate attrition occurred in this group. At the B.S. level, of those NS&E's who do not go on for an advanced degree, about two-thirds actually take jobs that are in NS&E fields, largely in business and industry. At the Ph.D. level, of those who enter the labor market, the largest shares will go to work for business and industry (50%) or universities and colleges (35%).

The natural sciences account for the majority of the NS&E degrees, more than 60% of the B.S. degrees, 55% of master's degrees, and 75% of the Ph.D.'s. Engineering B.S. degree-holders are about twice as likely as natural science B.S. degree-holders to acquire a Masters degree, but natural science M.S. degree-holders (or their equivalent) are about three times more likely than engineering M.S. degree-holders to acquire a Ph.D. The Masters degree is evidently becoming a significant edge over the bachelor's for professional engineers, and it confers full professional status in most engineering occupations. In contrast, the Ph.D. is needed for full professional status in most occupations in the natural sciences. The highest percentage of Ph.D. graduates in engineering and the natural sciences work for industry (60% and 45% respectively) with educational institutions being only the second most important locus of employment (25% and 40% respectively). Recent graduates with bachelor's degrees in engineering who acquired employment are working largely (e.g., 90%) in NS&E jobs, whereas recent B.S.-level graduates in the Natural Sciences are far less likely to become employed in NS&E jobs (57%).

Trends

The aggregate production of baccalaureate degrees in the natural sciences and engineering has exhibited a steady growth over the past twenty-five years (Figure 2a), while degrees in the social and behavioral sciences have fluctuated widely (not shown). The participation rate (Figure 2b) for NS&E B.S. degrees has been extremely stable, averaging about 4.1%. It has seen a small but steady growth in the last decade to 5.1% in 1984, largely due to an increasing participation by females. The conferral of NS&E B.S. degrees was virtually unaffected by the very large increase in the fraction of 22-year-olds completing baccalaureate programs in the 1960's (which rose from 18% to 27%) and the subsequent decline during the 1970's (27% to 24%). However, there are observable market-driven substitution effects between subfields within NS&E.

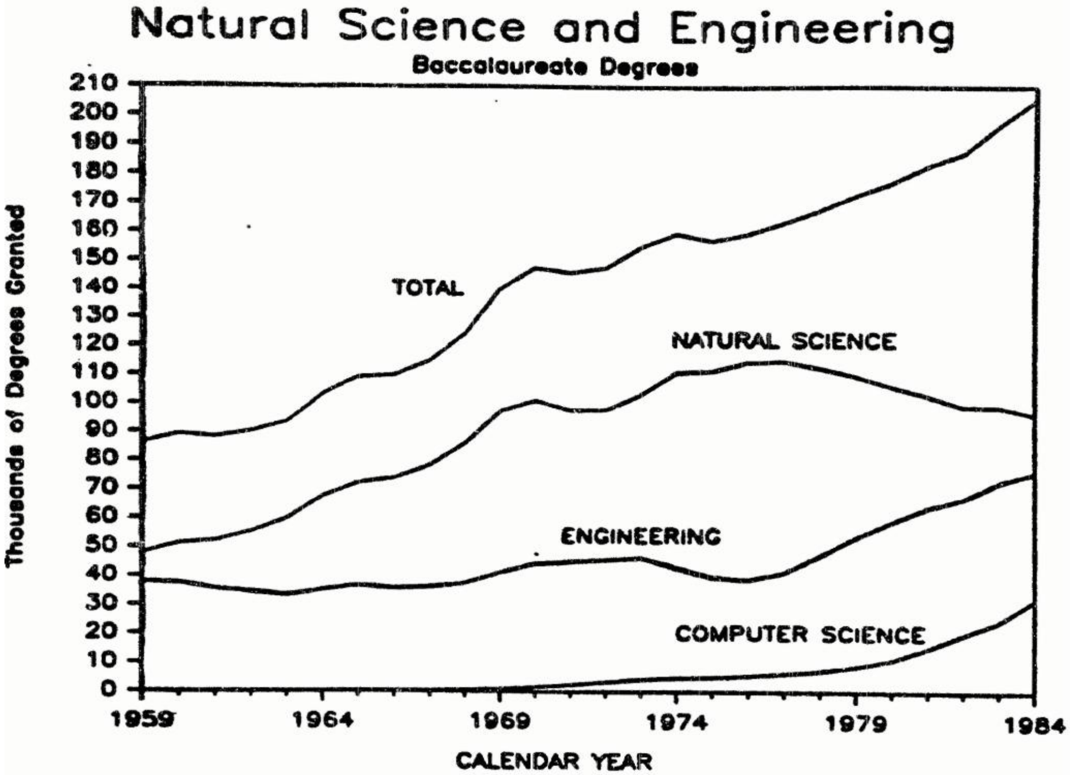

Figure 2a

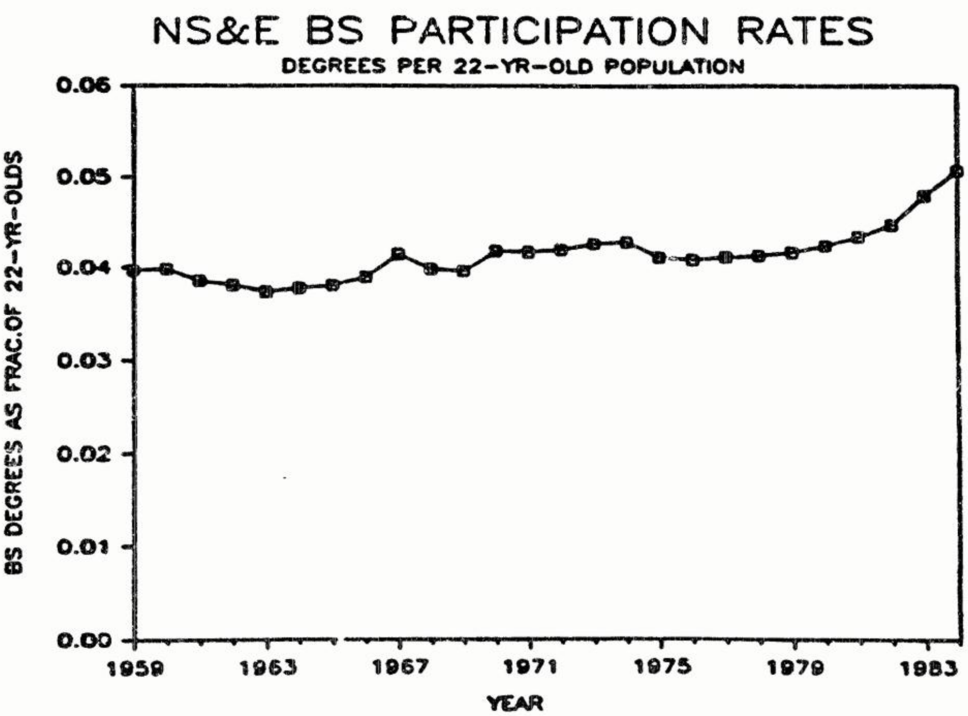

Figure 2b

From 1970 to 1973, life science degree participation by males rose 8% while that in mathematical, physical, and computer sciences fell 8%. From 1976 to 1980, male participation in engineering rose 32% while that for life sciences dropped 26%. New female baccalaureates in NS&E fields grew steadily from 1.5% of 22-year-olds in 1972 to 2.5% of 22-year-olds in 1982, but in the first five years the growth was entirely in life sciences, while in the latter five years growth was entirely in the remaining NS&E fields. During 1982-84, female NS&E baccalaureates rose to 3.0% of 22-year-olds.

Production of Ph.D.'s in NS&E has not been as stable as baccalaureate degrees. The rate more than tripled from 1959 to 1971, but dropped 20% from 1971 to 1978, and has now nearly recovered to the peak 1971 level (Figure 3). Much of this growth, however, is due to foreign students, of whom about one-third will not remain in the country. More than half of U.S. engineering Ph.D. degrees, for example, are now granted to foreign citizens.

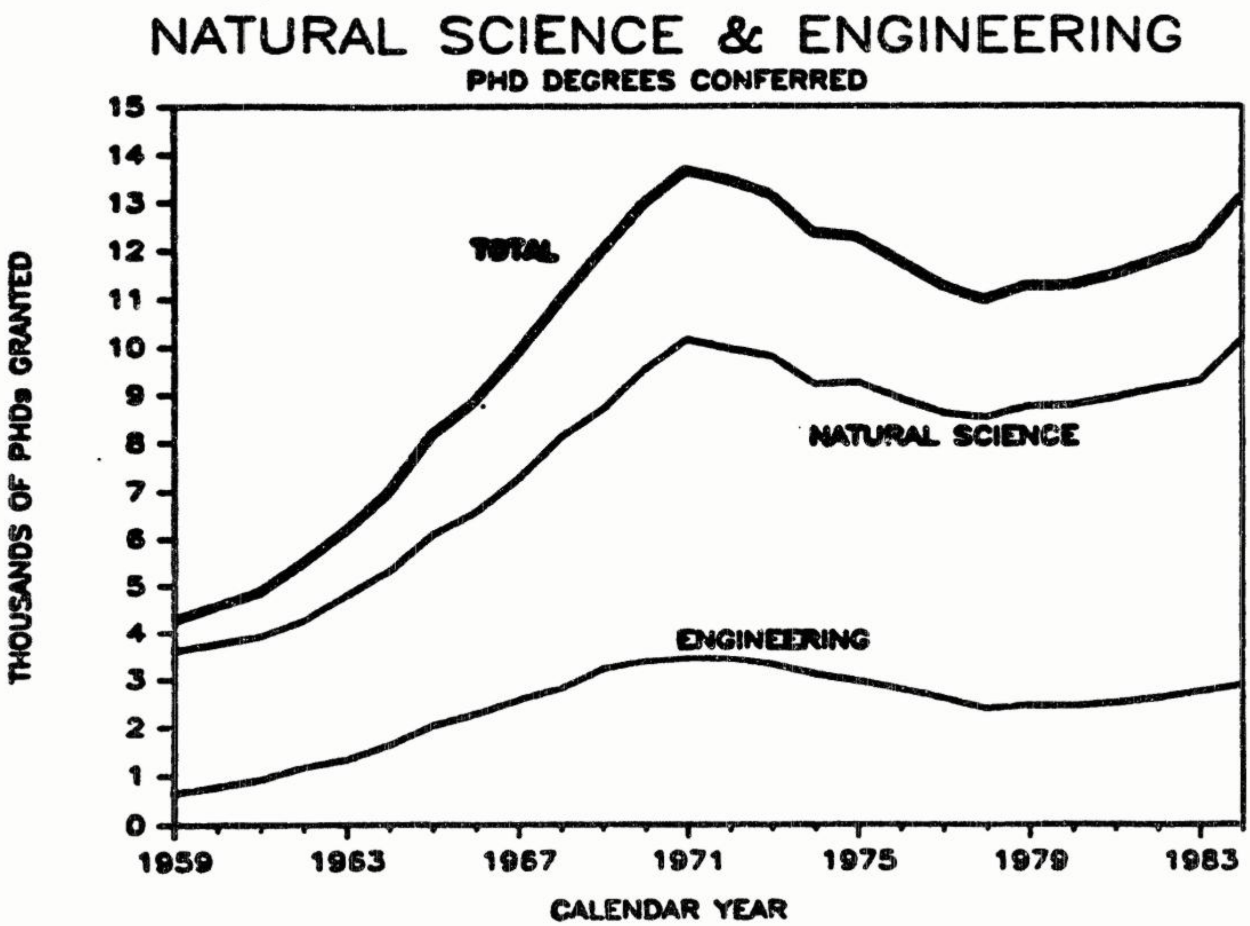

Figure 3

Utilization of Graduates

In addition to data on inflows to the stock of NS&E's, some information is available for comparing degrees with type of employment. Some field switching occurs as students move through the pipeline, and some NS&E graduates take first jobs (or switch into jobs) that can be considered non-NS&E. Of the total population with NS&E degrees at all levels, about three-fourths were employed in jobs classified as NS&E in 1986. In 1982, 19% to 28% of the new NS&E Ph.D.'s had received their B.S. degrees in NS&E different fields than the one in which they got their Ph.D. More interestingly, 9% of the new NS&E Ph.D.'s had received their B.S. degrees in non-NS&E fields. These percentages are representative of the field switching that occurred in earlier periods in the 1970's, and will probably prove to be lower bounds on field switching in later years, as the demand for NS&E Ph.D.'s strengthens.

NS&E degree-holders also shift frequently among the broad aggregate of NS&E occupations (Figure 4). A 1978 study by SRS (NSF) on the subject of where people had worked six years previously found that 30% of the experienced natural scientists and engineers in the study group had shifted to other S&E occupations (includes administrative positions) during that time period.

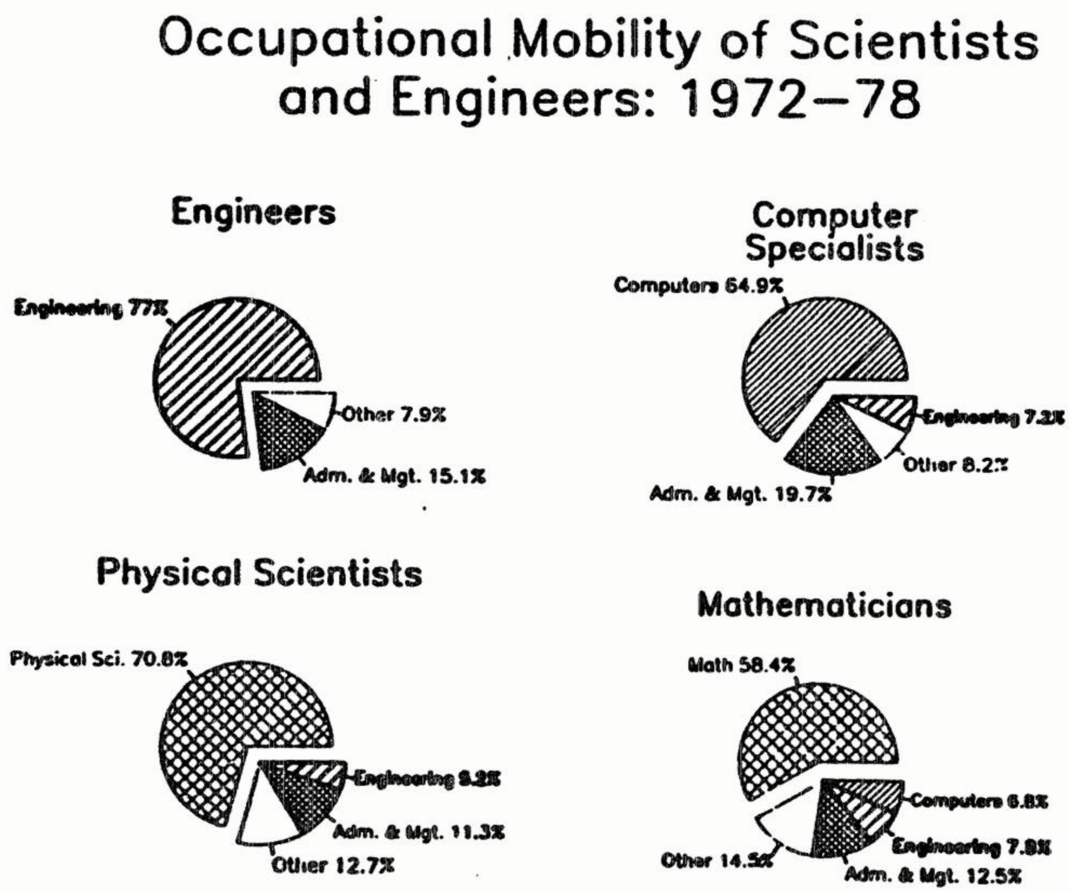

Figure 4

The Computer Science field demonstrates that a great amount of mobility can occur from "old" fields into new fields. Half of the computer scientists employed from recent graduating classes came from NS&E fields other than Computer Science. In fact, nearly 60% of all computer specialists in 1982 had B.S. degrees in fields other than Computer Science. At this degree level, students responded rapidly to the excellent first job prospects. The number of baccalaureate computer scientists rose from 11,000 in 1980 and 15,000 in 1981, to 20,000 in 1982, 25,000 in 1983, and 32,000 in 1984. At the doctorate level 13,500 Ph.D.'s were working in Computer Science in 1985, but only 3,100 (23%) had Ph.D.'s in that field. At the Ph.D. level, student response to strong demand has been much weaker, with annual Ph.D. conferrals rising from 240 in 1980 to an average of 286 in 1984 and 1985. A high degree of fungibility in the NS&E fields is an important source of response to shifts in market demand within the aggregate of NS&E occupations, especially during transition periods.

Institutional Origins of New Degree-Holders

Dividing the 4-year institutions into public and private doctoral granting universities and undergraduate colleges (4 categories) indicates that the contribution of each type to B.S. production and (ultimately) to successful Ph.D. candidacy has been fairly stable since the early 1970's (Figure 5). However, fairly major changes occurred from 1947 to the early 1970's in terms of a shift from private to public institutions of higher education. The number of public institutions grew from one-third to one-half of the total, and public enrollment grew from half to four-fifths of the total (including two-year schools). Seventy percent of the 1982 NS&E baccalaureate graduates came from the Public institutions (and 53% from Public universities). Private universities and colleges each accounted for 15%.

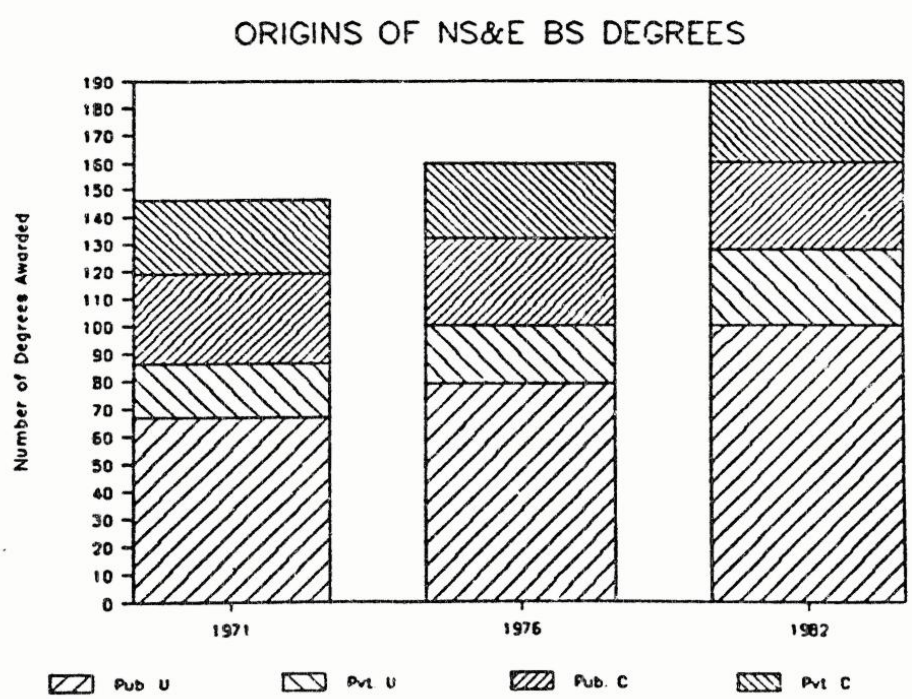

Figure 5

Because NS&E baccalaureates from private institutions have more than twice the proclivity to earn NS&E Ph.D.'s compared to their counterparts from public institutions, private institutions accounted for nearly as many of the U.S. B.S. degree-holders acquiring NS&E Ph.D.'s during 1981-1984 as did public universities. Foreign institutions accounted for nearly one half of the baccalaureates getting engineering Ph.D.'s (Figure 6).

Institutional Source of Bachelors' Degrees for Natural Science & Engineering Ph.D.'s Conferred in 1981–1984

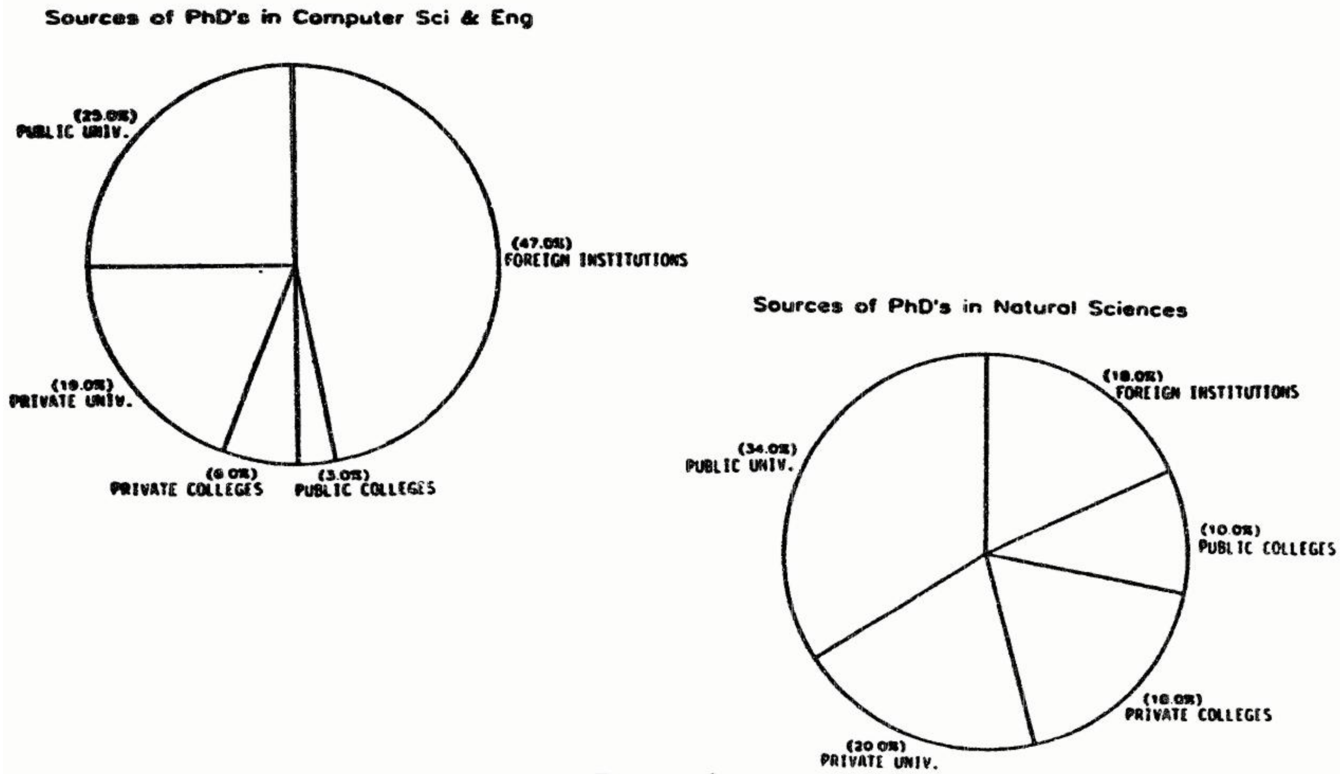

Figure 6

Although more than 1,400 institutions conferred B.S. degrees in NS&E fields in 1982, some granted only one degree, while others produced several hundred graduates. The bulk of degrees were produced by a few hundred schools. According to unpublished data from the National Center for Education Statistics, the top 100 universities (by research funding) and the top 100 4-year colleges (by production of successful Ph.D. candidates) together accounted for 50% of all B.S. degrees in 1982 and 61% of all baccalaureates earning NS&E Ph.D.'s during 1981-84. The upper 500 schools (some 35%) accounted for 87% of all NS&E B.S. degrees and 88% of all NS&E baccalaureates that acquired NS&E Ph.D.'s (Figure 7).