REPORT OF THE
AD HOC WORKING GROUP ON THE
SUPPLY OF SCIENCE, ENGINEERING AND MATHEMATICS (SEM) PROFESSIONALS

September 9, 1993

I. Background

Recent slack in the world economy and reductions in the US defense budget have decreased the current demand for scientists, engineers, and mathematicians. Is educational policy taking adequate account of these developments insofar as they contribute to a rapidly changing job market for scientists, engineers, and mathematicians? Does Federal government spending for the education of SEM professionals properly track this dynamic market, where new fields of specialization are continually created with their own new demands on our educational system while at the same time some already-educated workers are losing jobs and other newly trained workers are having a hard time finding jobs?

II. Purpose of the Working Group

The purpose of the Working Group, as described in its charge, is "to develop a broad, visionary statement of the Federal government's perspective on the issue of the supply of science, engineering and mathematics (SEM) professionals, particularly regarding future employment prospects ...[and to] assess the current SMETE (Subcommittee on Science, Mathematics, Engineering and Technology Education) priorities in the context of supply versus demand going into the next century."

III. What the Working Group Did

In order to meet its charge the Working Group has:

- reviewed the way that funding agencies inform themselves about the need for scientists and engineers
- reviewed relevant literature on forecasting the markets for scientists and engineers
- examined trends in spending for graduate student support and the distribution of support among SEM fields
- considered alternative approaches by which the education budget could better take account of current and prospective conditions in the SEM labor market.

Because of its short duration, the Working Group restricted the range of issues it considered. Priority was given to issues related to the deliberations of the FCCSET/CEHR Graduate Working Group. The Working Group did not evaluate supply issues related to paraprofessionals and technicians and did not attempt to summarize the literature dealing with the supply and demand for SEM professionals within specific fields. These are important issues that should be considered in the future.

IV. Current Federal Policy

A. The nature of the policy problem

The Federal government has supported scientific education for many years. Education is regarded as an investment in human capital that produces societal benefits that exceed Federal costs. As with all investments, however, there is the problem of determining the right amount to spend, and there is no easy answer. The decision making process is all the more difficult in that education is a very long-term investment; a scientist's career may last 40 years or more. Over that time, the market for scientists will probably go through several cycles of relative tightness and ease, when unemployment rates increase and decrease. Part of the policy problem is deciding how much consideration should be paid to the current supply and demand for SEM professionals, as opposed to long term national needs.

B. Planning activities in agencies that support SEM education

Currently, Federal agencies take a variety of approaches to obtaining information and analysis to support their education budgeting process. Generally, agencies with substantial graduate education programs devote considerable effort to understanding relevant trends in the supply and demand for SEM graduates for their planning and budget formulation processes. Their work uses data from several Federal statistical agencies. More specifically:

1. *Bureau of Labor Statistics, Department of Labor.* BLS collects the basic statistics on the U.S. labor force, including that for SEM professionals. It also produces projections of the SEM labor force. The February 1992 *Monthly Labor Review* presents projections dealing with scientific and technical employment. BLS has explicitly attempted to take account of the effects of defense downsizing and long term economic trends.

2. *Department of Health and Human Services.* The National Institutes of Health supports national programs of training grants and fellowships at the predoctoral and postdoctoral levels in the biomedical sciences. It is required by Congress to evaluate their training programs in light of the supply and demand for scientists in the health professions every four years. These evaluations have been conducted by the National Academy of Sciences, using

a combination of mathematical projections and expert opinions. In addition, the NIH is conducting numerous studies and evaluations of these programs, as well as improving data collection.

3. *National Science Foundation.* The Directorate of Education and Human Resources (EHR) funds graduate fellowships and traineeships, among other forms of support for graduate students. Fellowships are regarded as a way to identify and recognize outstanding individuals and to provide incentives to such individuals for the long-term benefit of the nation, not as a solution to perceived short-term personnel needs in specific sub-fields. For the traineeships, EHR does not rely on formal projections, as NIH does, but rather depends upon other scientific directorates in the Foundation to recommend the direction of support to specific fields where targeted funds could make a difference. The Science Resources Studies Division collects data on the number and characteristics of scientists and engineers in the United States and has supported research on modeling the market for SEM professionals.

4. *Department of Defense.* Within DoD each of the individual services forecast requirements for SEM professionals based upon their respective budgets. The Office of Military Manpower and Personnel Policy applies the Secretary of Defense's strategic vision and a total force-mix is prepared. Short range forecasts are applied to hiring of SEM professionals and awarding of research grants while long range forecasts are applied to ROTC and Service Academy curriculums. Additionally there are any number of recent and ongoing analytic efforts elsewhere that deal with the issue of defense conversion. (OTA, CBO, BLS et al.)

5. *National Center for Education Statistics, Department of Education.* NCES produces statistics and projections related to education in this country. Their work is used by other agencies in estimating the supply of future degree recipients and for projecting the likely demand for faculty from projections related to student enrollment.

6. *Department of Energy.* DOE supports studies of future labor market trends and the adequacy of supply of new graduates for the general energy-related field and for specific energy-related programs or areas. DOE also supports workshops and conferences to bring together representatives from academia, utilities, labs, private firms, and government to discuss the adequacy of the supply of new graduates and the education needs for specific energy-related fields.

7. *Department of Agriculture.* Comprehensive national studies were undertaken in 1980, 1985, and 1990 by the USDA Office of Higher Education Programs (HEP) to determine scientific and professional opportunities for new college graduates in the food and agricultural sciences. In 1991, HEP, in conjunction

with Purdue University, issued the third report on the labor market for such individuals--Employment Opportunities for College Graduates in the Food and Agricultural Sciences 1990-1995. These studies examine Bureau of Labor Statistics employment data by industry and occupation and use Department of Education statistics on degrees awarded in the various fields.

To better understand and project the market for agricultural scientists and engineers, USDA commissioned the National Research Council's Board on Agriculture to analyze existing data and studies. In 1988, they published *Educating the Next Generation of Agricultural Scientists.*

8. *National Aeronautics and Space Administration.* NASA relies primarily on the recommendations of its researchers at the agency and their colleagues at the universities (e.g., the Space Science Advisory Committee) for advice on supply in emerging fields. Precise projections are based on the work of others.

Some of these planning efforts involve interagency cooperation in order to share the costs of modeling and data collection work. For example, the Survey of Doctorate Recipients, which provides data on doctoral SEM professionals, is funded jointly by NSF, NIH, and DOE. These data are also used in an academic labor market model funded by NSF, NCES, and the Nuclear Regulatory Commission.

In addition, several professional associations collect data on current conditions on labor markets for their members. For example, the annual survey by the American Mathematical Society and the Mathematical Association of America, begun in 1957, reports regularly on the market for mathematicians. The American Chemical Society surveys recent degree recipients and tracks their help wanted advertisements to measure the labor market for chemists and chemical engineers. The Engineering Workforce Commission (formerly the Engineering Manpower Commission) and the Institute of Electrical and Electronics Engineers devote considerable resources to analyses of supply and demand factors in the engineering labor market both nationally and internationally.

These efforts taken together, however, do not necessarily constitute a comprehensive overview sufficient to guide the overall education budget process. Any such overview would have to cover not just individual agency needs for skilled professionals, but also would have to consider the supply of such professionals in the context of the overall SEM labor market, both the public and the private sector. For example, the long term consequences of the defense budget reductions as they affect the private sector demand for SEM professionals need to be considered in formulating Federal budget policy for training.

C. Other Federal goals related to programs affecting SEM supply

The education programs likely to impact SEM supply are complex and are designed to address multiple goals. This complexity must be taken into account when contemplating funding changes. More specifically, it is important to recognize that:

- Enhancing K-12 science and mathematics education is vital to achieve a literate work force and should not be viewed primarily as a means to impact the supply of SEM professionals.

- The Federal government's role with respect to undergraduate education has been primarily to ensure that talented and motivated students have an opportunity to attend college regardless of family income.

- Most of the Federal support for graduate students is channeled through Research Assistantships (in 1991 almost two thirds of those SEM graduate students primarily supported by the Federal government were supported by Research Assistantships). Funds for Research Assistantships are part of the Federal support for research and are not under the purview of CEHR.

- The Federal government's goal in graduate education has in large part been one of improving the quality of graduates in fields identified as being of high importance. This is reflected in the distribution of current graduate support by discipline (Attachment A). Targeted fields are ones in which the Federal government is a relatively important employer and/or ones perceived as vital for meeting important national goals. (cf. Stephens--NRC Conference)

- Since postdoctoral appointees already are qualified for SEM employment, these programs can be viewed as primarily skill enhancement programs.

- A factor in many programs at all levels is to increase participation of underrepresented groups in SEM education.

D. The role of Federal policy in the supply of SEM professionals

The Federal government is an important source of funding for SEM education, but it is well under half of total support (Attachment B). Twenty-one percent of graduate students obtain their primary support from the Federal government. Federal fellowship and traineeship support is less important relative to total funding of SEM graduate education than it was 20 years ago. Only six percent of graduate students receive their primary support from Federal fellowships or traineeships. Further, in recent years there has not been much year-to-year fluctuation in the percentage of graduate students receiving support (Attachment A). The FCCSET-CEHR budget has been fairly steady in recent years, consistent with a moderate "steady state" approach to funding graduate education. While there has not been an extensive study of the impact of Federal funding for

fellowships and scholarships on the supply of SEM professionals, these figures imply that the Federal government does not strongly influence the total supply of SEM graduates through its funding of graduate fellowships and traineeships.

Nonfederal sources of support--which exceed Federal support in virtually every field--are more sensitive to current conditions in the labor market. Furthermore, career choices made by prospective science students take into account not just available Federal support but also information on future employment prospects. Therefore, some degree of adjustment to market conditions takes place, apart from whatever happens in the Federal budget process.

V. Current State of Knowledge about Forecasting SEM Labor Markets

A. A brief summary of relevant literature

The following statements reflect the current state of knowledge on forecasting SEM labor markets. They are drawn from the literature in the field and, in our view, represent a consensus of research findings.

1. It is not currently possible--and will probably never be possible to predict with a high degree of accuracy--quantitative shortages or surpluses of scientists and engineers several years into the future. (Finn & Baker, Vetter, McFadden, Pings, Kutscher, Oaxaca--NRC Conference, Fechter -- NRC Conference, Braddock, Leslie & Oaxaca, Gill, Norrell, & Kipplinger) Limitations on projections are especially severe for demand, since demand is a function of the economic cycle and of global events that are difficult, if not impossible, to predict. For example, a few years ago no one would have predicted the end of the Cold War that precipitated the current defense downsizing. Nevertheless, the existing state of the art does allow the production of projections that aid in the understanding of causal factors and can at least signal substantial changes in SEM labor markets. Furthermore, informed judgment will always play an important role.

2. The major studies in the field indicate that the market for scientists and engineers behaves according to the normal laws of supply and demand, i.e., when supply shortages or surpluses occur, market forces eventually prevail to bring the system closer to equilibrium. (Finn & Baker, Leslie & Oaxaca, Forest)

3. Projecting the supply of and demand for SEM professionals is further complicated by the fact that trends in supply and demand can vary markedly among SEM fields. Thus, shortages in specific SEM fields can exist simultaneously with surpluses in other fields. Further, there is considerable fungibility among occupations, i.e., positions are often filled by individuals who have training in fields other than that

field most closely related to their occupation. (NSF, Dauffenbach & Fiorito, Lerner, Dauffenbach, NRC)

4. The downsizing of defense is having significant impacts on the demand for scientists, engineers, and mathematicians (cf. Saunders, Braddock, NSF)

5. The effects of developments in the global economy on the supply and demand for scientists and engineers is difficult to estimate, particularly in the longer term. These effects involve changes in trade in technology-intensive goods, as well as movements of scientists and engineers. While immigration has often been a balancing factor in the past, this may not be feasible in the future. (Vetter)

B. The outlook for SEM labor markets

Given the difficulties of making accurate forecasts of SEM labor markets, the Working Group does not consider itself able to present any definitive forecasts. Clearly the market for new SEM professionals is weak at the present time, though we must emphasize that unemployment rates for SEM professionals remain substantially lower than the civilian unemployment rate for the economy overall and comparable to that of other professional occupations (Attachment C). The real problem for budget planning is to determine as accurately as possible what conditions will prevail five years or more from now. There are at least two possible views on this:

1. *"Things will get better as current problems work themselves out."* According to this view, the most important factors causing weakness in the labor markets are slow economic growth in the United States and other industrial nations, and the downsizing of the defense budget. Apart from the repercussions of these factors, education of SEM professionals does not appear to have overshot the mark. Defense downsizing is not a permanent condition; in a few years the defense budget will have reached a new steady state. The economy is likely to improve. Long term trends in all industrial economies have featured a steady growth in technology and in the employment of SEM professionals. These trends will continue.

2. *"Economic fundamentals have changed in ways that SEM education policy must recognize."* According to this view, current conditions are not part of the normal business cycle, but part of a basic change that is not yet fully appreciated. The change involves shifts in international competitiveness, whereby other nations will compete ever more vigorously in technology, with consequences for SEM labor markets. It is unclear whether the big U.S. technology companies will bounce back from their current problems. At the very least, the Federal government should moderate its support for the production of new SEM professionals until the situation is better understood.

While the Working Group tends to favor the first, more optimistic view, agreement is not unanimous. Moreover, we do not have the expertise, nor have we spent enough time investigating this question, to be able to present clear findings to the Committee.

VI. Implications for Federal Policy

The Working Group's recommendations fall into three categories: (a) improvements in information collection and dissemination related to SEM labor markets; (b) assuring that programs are flexible enough to respond to changes in these markets when necessary; and (c) important considerations related to CEHR support for graduate students.

A. Better information and dissemination so that more intelligent choices can be made, by educators, government, and students

1. Existing projection techniques are not accurate enough to serve as the sole basis for planning education budgets. Nonetheless, methods such as those used by NIH, the Department of Energy and others (described above) are useful. The Working Group recommends that other agencies consider conducting similar studies, recognizing that such efforts are called for only when training budgets are relatively large and when they make sense in terms of the agency's mission.

2. Formulating sound policy on education requires better data and projection models than are currently available. Federal agencies should, therefore, consider increasing their funding for data collection and analysis activities related to projecting the supply and demand for SEM professionals. Members of this Working Group found the Survey of Doctoral Recipients particularly useful and recommended that its sample size be increased. The Graduate Working Group report details some of the needed data improvements.

3. The Committee may wish to consider ways of drawing together existing studies conducted by the Federal government, professional associations, and academia into a comprehensive outlook for the SEM labor market, again recognizing the many uncertainties associated with labor market projections.

4. Federal agencies should coordinate data collection and projection efforts among themselves and with the professional associations. In addition to projections, it would be useful to have a clear picture, regularly updated, of existing market conditions.

5. The results of the current and future data collection and projection efforts should be disseminated widely in order that students, educators, and career counselors can benefit from the best information available.

B. More flexibility in education programs so that SEM graduates can adapt more easily to changes in labor market conditions

Given the difficulty of predicting shortages and surpluses in the labor market, the Committee may wish to consider whether it can formulate programs that can increase the flexibility of our educational system, while still maintaining or increasing quality. The objective of the following set of recommendations is to produce graduates who can more easily shift from one type of employee field to another, should employment and research opportunities change. More specifically:

1. The long time lag between when final career decisions are made by students and their entry into the work force makes it difficult for students to base their decisions on accurate projections of likely job market conditions. Students should be encouraged to follow less specialized educational paths so that when they enter the labor market they have a wider choice of jobs. To this end, students need to be aware of employment prospects in different fields and have the opportunity to earn degrees with broader curricula if they so choose.
2. In order to enhance the lifetime flexibility of SEM professionals, graduate education needs to place greater emphasis on multidisciplinary studies and research.
3. Students, career counselors, and educators need to become more aware of employment opportunities in the governmental and industrial sectors. This may require appropriate curriculum modification in addition to heightened sensitivities to these opportunities.
4. Graduate training should emphasize the life-long need of SEM professionals to adapt to changing technology and changing market conditions.
5. More emphasis should be given to programs designed to retrain SEM professionals facing unemployment and/or underemployment resulting from major long-term shifts in the demand for SEM professionals in selected fields. For example, targeted retraining programs can assist individuals in fields heavily impacted by defense downsizing and simultaneously help fill the Nation's need for additional SEM graduates in shortage fields more efficiently than training recent college graduates.
6. In those education programs that provide student support in areas targeted to national needs, the design of such programs should provide appropriate flexibility for changing the target areas with minimal lead time in order to maximize the benefits of Federal student support to the nation.

C. Important considerations related to CEHR support for graduate students

1. The goal of maintaining or increasing the *quality* of graduate students and graduate programs continues to be a primary goal. Since decreasing funding for graduate incentive programs may well have a negative impact on quality and since we are

unclear that we are witnessing more than a temporary oversupply of SEM professionals in certain fields, the Working Group does not recommend cuts in these programs.

2. The goal of increasing participation in the SEM work force of underrepresented minorities, women, and individuals with disabilities is another goal of high importance to the Federal government. Not only is equity a basic goal of the Federal government in all its programs, but artificial restrictions to participation in SEM education serve to dilute the quality of the SEM work force. It is, therefore, vital that any proposed changes to funding patterns for educational programs be evaluated carefully for possible impacts on equity goals.

3. Given the lack of a clear, widely accepted forecast of the market for SEM professionals, the Committee should be cautious in setting quantitative national goals for producing specific numbers of SEM graduates.

4. Given the questions that remain about the outlook for SEM labor markets, the Committee may wish to seek advice from experts in the field. However, we doubt that a clear answer will be forthcoming.

_____

Kenneth M. Brown
Chairman
National Science Foundation
Division of Science Resources Studies

MEMBERS AND ALTERNATES
AD HOC WORKING GROUP ON THE SUPPLY OF SCIENCE, ENGINEERING AND MATHEMATICS (SEM) PROFESSIONALS

Department of Agriculture:	Gwendolyn L. Lewis
Department of Commerce:	Carl Shepherd
Department of Defense:	Jasper C. Lupo Russell Herndon
Department of Education:	Thomas Corwin Debra Gerald Ron Marin
Department of Energy:	Michael L. Wolfe Larry M. Blair (ORISE)
Department of Health and Human Services:	Anthony Boccanfuso (NIH) John C. Norvell (NIH) Walter Schaffer(NIH)
Department of Interior	Paul Dresler
Department of Labor:	Doug Braddock (BLS) David T. Duncan Ron Kutscher (BLS)
Department of Veterans Affairs	Charlotte Beason
National Aeronautics and Space Administration:	Sherri McGee Stephanie Jerome Frank Owens
National Science Foundation:	Lida K. Barrett Kenneth M. Brown Deborah Lockhart Terence Porter Carolyn F. Shettle

ATTACHMENT A

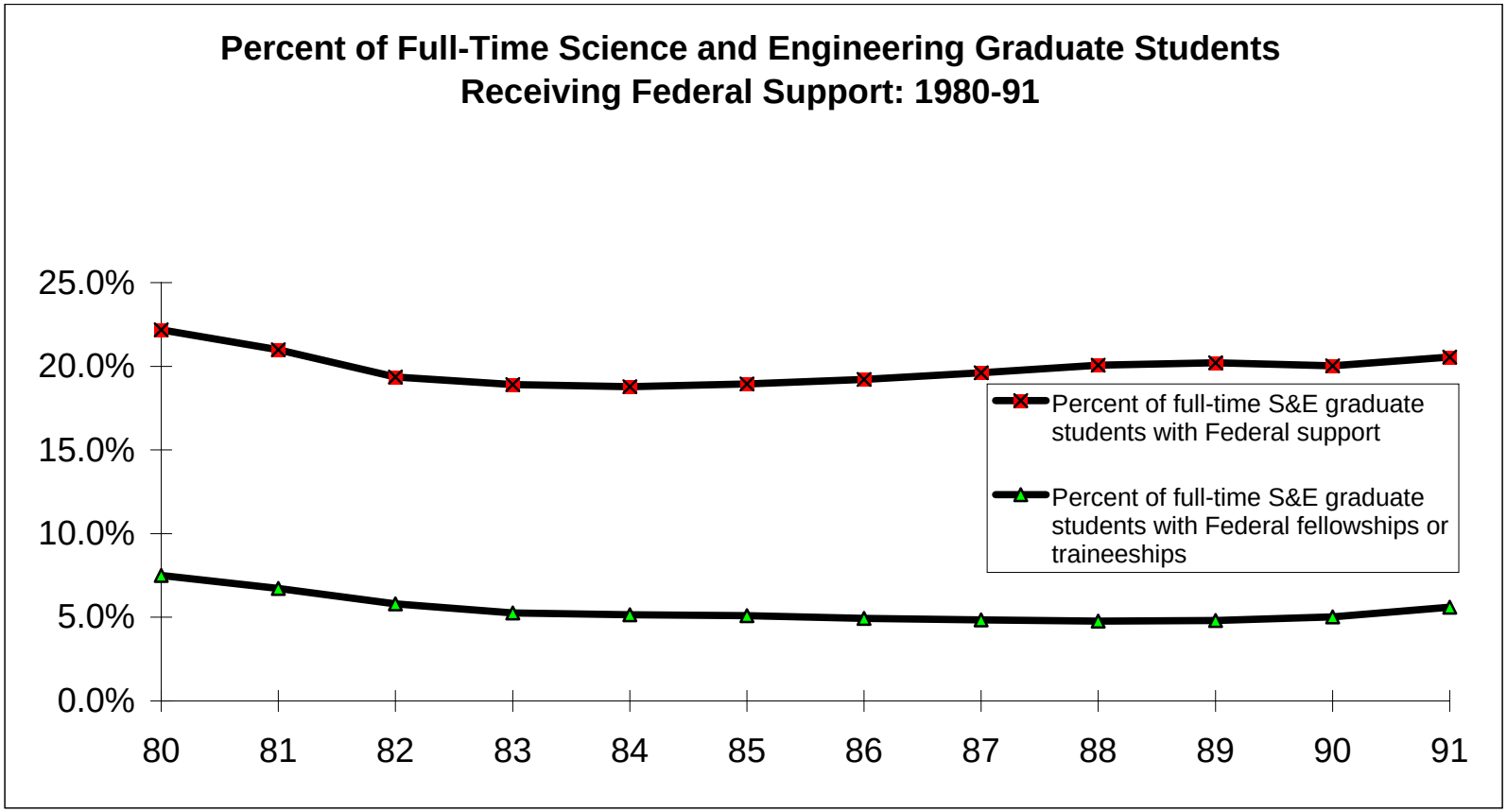
Distribution of Federal Support for Graduate Students, by Field: 1991

Academic discipline	Graduate Students		
	Number	Percent with Federal support	Percent with Federal fellow-ships or trainee-ships
TOTAL OF ALL S&E DISCIPLINES	308,669	20.6%	5.6%
ENGINEERING	71,230	22.5	3.2
Aerospace Engineering	3,314	40.5	4.9
Chemical Engineering	6,309	26.2	4.5
Civil Engineering	11,214	15.6	2.0
Electrical Engineering	19,988	19.8	2.5
Industrial Engineering	5,705	12.6	1.7
Mechanical Engineering	11,654	23.7	3.4
Materials Engineering	4,059	35.6	4.4
Other Engineering	8,987	27.0	4.7
PHYSICAL SCIENCES	30,131	36.0	5.7
Astronomy	810	45.4	9.8
Chemistry	16,696	33.2	5.8
Physics	12,482	39.5	5.3
Other Physical Sciences	143	14.0	1.4
GEOSCIENCES	10,414	29.6	3.1
Atmospheric Sciences	859	65.5	5.0
Earth Sciences	5,691	24.0	2.6
Oceanography	1,898	46.1	4.0
Other Geosciences	1,966	14.4	3.0
MATH AND COMPUTER SCIENCES	30,811	13.1	2.6
Mathematics and Statistics	14,259	10.5	4.1
Computer Science	16,552	15.3	1.3
LIFE SCIENCES	82,938	28.5	12.0
Agricultural Sciences	9,238	20.1	1.5
Biological Sciences	42,929	33.8	11.5
Medical Sciences	10,968	24.9	14.4
Other Life Sciences	19,803	22.8	16.8
PSYCHOLOGY	32,382	8.3	2.4
SOCIAL SCIENCES	50,763	6.2	2.8
Economics	11,733	6.9	2.7
Political Science and Public Administration	16,126	4.4	2.2
Sociology	6,533	6.7	3.2
Anthropology	5,036	6.0	3.8
Linguistics	2,597	5.8	3.1
History of Science	340	10.0	7.1
Other Social Sciences	8,398	8.3	3.1

* Most students receiving Federal support other than fellowships or traineeships receive research assistantships.

SOURCE: National Science Foundation/SRS, Survey of Graduate Students and Postdoctorates in Science and Engineering

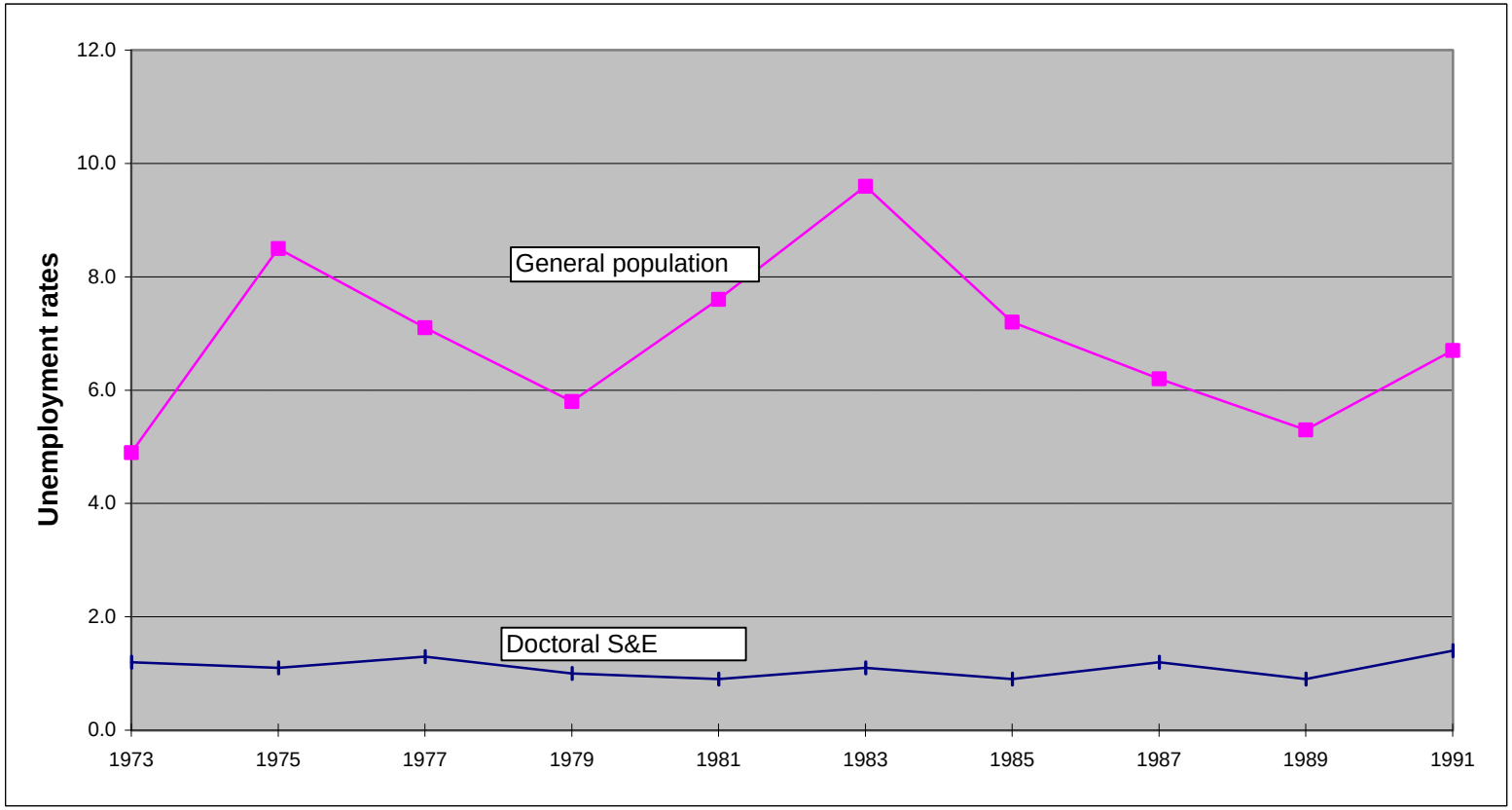
ATTACHMENT B



SOURCE: National Science Foundation/SRS, Survey of Graduate Students and Postdoctorates in Science and Engineering

ATTACHMENT C

April unemployment rates of persons with doctoral degrees in science and engineering and U.S. civilian labor force 16 years and older : 1973-1991



SOURCES: Doctoral statistics from National Science Foundation/SRS, Survey of Doctorate Recipients. General population figures from Bureau of Labor Statistics, Current Population Survey.