ICS REGISTRY

4207
4206
4205
4204
4203
DCI/ICS 82-4202
24 February 1982

MEMORANDUM FOR: Executive Director, CIA

FROM: [redacted] 25X1
Director, Intelligence Community Staff

SUBJECT: Technical Manpower Study

John —

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

Approved For Release 2007/04/27 : CIA-RDP84M00395R000600050034-4

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the Central Intelligence Agency. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In order to facilitate the study please submit the name of your action officer to [redacted], of the Intelligence Community Staff who is providing staff support to the project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U) 25X1

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to the CIA and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

CONFIDENTIAL

Director
Intelligence Community Staff
Washington, D.C. 20505

DCI/ICS 82-4203
24 February 1982

MEMORANDUM FOR: Lieutenant General Lincoln D. Faurer, USAF
Director, National Security Agency

SUBJECT: Technical Manpower Study

Linc -

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

25X1

CONFIDENTIAL

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the National Security Agency. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In order to facilitate the study please submit the name of your action officer to [redacted], of the Intelligence Community Staff who is providing staff support to the project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U) 25X1

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to NSA and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

Approved For Release 2007/04/27 : CIA-RDP84M00395R000600050034-4

Director
Intelligence Community Staff
Washington, D.C. 20505

DCI/ICS 82-4204
24 February 1982

MEMORANDUM FOR: Lieutenant General James A. Williams, USA
Director, Defense Intelligence Agency

SUBJECT: Technical Manpower Study

Jim –

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

25X1

Approved For Release 2007/04/27 : CIA-RDP84M00395R000600050034-4

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the Foreign Science and Technology Center, the Missile Intelligence Agency and the Medical Intelligence and Information Agency. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In order to facilitate the study please submit the name of your action officer to [redacted]. 25X1
[redacted], of the Intelligence Community Staff who is providing staff support to 25X1
the project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U)

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to Army intelligence and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

CONFIDENTIAL

Director
Intelligence Community Staff
Washington, D.C. 20505

DCI/ICS 82-4205
24 February 1982

MEMORANDUM FOR: Brigadier General William E. Odom, U.S. Army
Assistant Chief of Staff for Intelligence
Department of the Army

SUBJECT: Technical Manpower Study

Bill —

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

25X1

CONFIDENTIAL

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the Defense Intelligence Agency only. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In order to facilitate the study please submit the name of your action officer to [redacted] of the Intelligence Community Staff who is providing staff support to the project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U) 25X1

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to DIA and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

CONFIDENTIAL

Director
Intelligence Community Staff
Washington, D.C. 20505

DCI/ICS 82-4206
24 February 1982

MEMORANDUM FOR: Major General John B. Marks, USAF
Assistant Chief of Staff for Intelligence
Department of the Air Force

SUBJECT: Technical Manpower Study

John -

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

25X1

CONFIDENTIAL

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the Foreign Technology Division only. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In order to facilitate the study please submit the name of your action officer to [redacted], of the Intelligence Community Staff who is providing staff support to the project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U) 25X1

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to Air Force intelligence and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

Director
Intelligence Community Staff
Washington, D.C. 20505

DCI/ICS 82-4207
24 February 1982

MEMORANDUM FOR: Rear Admiral Sumner Shapiro, USN
Director of Naval Intelligence
Department of the Navy

SUBJECT: Technical Manpower Study

Shap -

1. The Science and Technology Advisory Panel (STAP) has been asked by the DCI to investigate the subject of the Intelligence Community's need for technical manpower. This subject is part of the broader manpower issue which was identified in the 1985 Intelligence Capabilities Study as requiring special attention for purposes of long-range planning. Among the concerns addressed in the individual agency papers submitted during the course of that study, the requirement for technically qualified civilian manpower stood out in terms of its universality and potential severity. (C)

2. The Intelligence Community has a need for engineers, physical scientists, and computer scientists to fill positions as analysts, researchers, and contract monitors. The Community's ability to recruit and retain qualified and talented manpower is likely to diminish during the decade as the competition from the private sector for a dwindling supply of technically qualified personnel becomes more intense. The situation is serious, and will grow more so unless steps are taken now to address the underlying causes. With your help, the STAP proposes to review the Community's technical manpower hiring and retention practices. It will make specific recommendations which could be translated either into specific program initiatives, or into modifications of personnel policy procedures. (C)

25X1

Approved For Release 2007/04/27 : CIA-RDP84M00395R000600050034-4

3. To accomplish this, I am asking for your assistance in responding to the attached questionnaire for the Naval Intelligence Support Center only. Where possible, the Panel has asked for data on civilian personnel only; where they have asked for categorical breakdowns, they are looking for consistency more than precision. A report by the National Science Foundation on the supply of qualified science and engineering manpower has been included to help place the Community's concerns in context. In o[redacted] please submit the name of your action officer to [redacted], 25X1 of the Intelligence Community Staff who is provi[redacted] project; he will be available to answer any questions you may have about the undertaking. A response by mid-April 1982, would be of great benefit. (U)

4. I am hopeful that this effort on the part of the STAP will result in tangible benefits to Naval intelligence and to the Community. (U)

[redacted] 25X1

Attachment:
a/s

SUBJECT: Technical Manpower Study

Distribution (DCI/ICS 82-4202
DCI/ICS 82-4203
DCI/ICS 82-4204
DCI/ICS 82-4205
DCI/ICS 82-4206
DCI/ICS 82-4207)
Original - Addressee
1 - D/ICS
1 - OP Subject
1 - OP Chrono
1 - ICS Registry

DCI/ICS/OP [redacted] (4 January 1982) 25X1

The Recruitment and Retention of Personnel with Scientific and Engineering Backgrounds

I. Present and Future Staffing

For purposes of this study, we have divided the Community's science and technology population into the following disciplines and job descriptions:

	ANALYST	RESEARCH AND DEVELOPMENT	CONTRACT MONITOR
Computer Scientists			
Physical Scientists			
Engineers			

-- Please complete the above matrix for your organization as of 30 September 1981. For each cell, provide the number of positions authorized, and the number of positions that were filled as of that date.

-- Please complete a similar matrix for your organization for FY 1987; provide only the number of positions being requested.

-- In those instances where personnel shortfalls have existed for prolonged periods, what measures has your agency taken to cope with the situation? What have been the consequences of these measures?

II. Recruitment

-- What are your general recruitment procedures with respect to technical personnel?

-- What special efforts are being made to attract the categories of technical personnel listed above?

-- To what extent are professional groups being called upon to assist?

-- Is any one category more difficult to recruit than another? Easier than another?

-- Are there administrative procedures or requirements that impede the hiring of technical personnel?

III. Retention

-- What are the attrition rates in the above categories and how do they compare with other categories of professional employees?

-- What in the way of pay and incentives is being considered to reduce the disparity between what is offered in the private and the public sectors?

-- What is being done now or is under consideration in the area of job enrichment directed specifically at technical personnel?

-- What other actions are being taken to retain these categories of employees?

IV. Training

-- How would you characterize the objectives of that portion of your training program directed at the categories of individuals under discussion?

-- What in-house training do technical personnel receive to qualify them for the particular job for which they were hired? To keep them current in their technical field?

-- What opportunities exist for external training? To obtain an advanced degree? To undertake independent research? To take a sabbatical?

-- How is training, internal or external, integrated into an individual's program for career development?

V. Other

-- How do you assess your capability to fulfill your technical manpower needs for the remainder of the decade?

-- Please feel free to comment on any aspect of this study not already touched upon.

Science & Engineering Education for the 1980's & Beyond

Prepared by the National Science Foundation &
the Department of Education

October, 1980

II. Supply and Demand for Science and Engineering Personnel

Judged from an economic perspective, the Nation's science and engineering labor force can be defined as being adequate at any given time if there are enough trained personnel in all occupational specialties and at all degree levels to produce the goods and services demanded by society. Alternatively, we could attempt to derive science and engineering personnel requirements by defining a set of social objectives, regardless of whether those objectives were currently revealed in the marketplace for goods and services. Such sets of social objectives might require that our society use scientific and engineering personnel in ways that are quite different than at present. One could then explore options for direct or indirect Federal intervention to create actual jobs for the requisite number and mix of scientists and engineers. However, there are a large number of combinations of social objectives and no unique, value-free way to select one combination as being superior to all others. To define national needs in terms of alternative social objectives therefore implies a set of value judgments that would have to be imposed on society and would be inappropriate for particular Federal agencies to make. For this reason, this section assesses the quantitative adequacy of the Nation's science and engineering labor force, now and for the next decade, relative to the jobs that currently exist in various science and engineering specialties, and the number that are likely to be created by the market, given Federal decisions being made now to increase defense expenditures, to create a synthetic fuels industry, and to balance the budget. These projections *do not* consider the effects on employment of the emergence of new technologies which can offer more efficient ways to produce existing goods and services or introduce new goods and services into the economy.

A. Current Balances Between Supply and Demand

Summary of Current Situation

Four types of indicators were examined to assess the current relative balance between the supply of and demand for various occupational categories of science and engineering personnel: (a) unemployment rates; (b) judgments by employers of the difficulty of filling job vacancies; (c) changes in relative salaries for new entrants into particular fields; and (d) the mobility of personnel within science and engineering fields and between science and engineering and other fields. The first two indicators measure static conditions at a particular time. The latter two reflect adjustments made by the market to correct personnel shortages and surpluses.

An assessment of current market conditions for science and engineering personnel based on these sets of indicators appears later in this section. Taken together with additional information submitted for this review, they lead to the following conclusions:

- There are current shortages of computer professionals at all degree levels and tight markets* at all degree levels in most engineering fields.
- University engineering schools and schools and departments which train computer professionals are un-

* Throughout this section the terms "tight market" and "strong market" are used to indicate that employers have difficulties finding qualified applicants to fill existing job openings.

able to fill existing doctoral faculty positions, a condition that reflects the strong industrial market in these fields. Moreover, the American Society of Engineering Education reports that engineering and computer departments are also experiencing difficulties in retaining both their junior and senior faculty.[1] In contrast, openings for Ph.D.'s in the academic sector are scarce in all fields of the mathematical, physical, biological, and social sciences.

- Employers in the industrial sector report that there are more than enough qualified physicists, chemists, mathematicians, and biologists. Trends in mobility data, however, suggest that the demand for chemists may be increasing faster than the supply. Despite the adequacy of personnel in these broad fields, spot shortages (particularly at the Ph.D. level) are reported in several subspecialties, notably solid-state and plasma physics, optics, analytical and polymer chemistry, and toxicology.[2]
- The Department of Defense reports problems in recruiting and retaining both civilian and military engineers because of the generally superior career opportunities in nonmilitary employment.
- Many secondary schools report vacancies for teachers in mathematics and the physical sciences, despite ample supplies of people with bachelor's and master's degrees in these fields[3] (Section V-D).

1. *Unemployment Rates*

Only about 1.5 percent of the 2.5 million scientists and engineers in the 1978 labor force were unemployed, as compared to 6.0 percent unemployment for the total civilian work force.[4] The lower level for science and engineering workers reflects their high degree of training relative to the remainder of the work force as well as intense activity in the Nation's science and engineering enterprise. The very tight market for computer professionals was evident in an estimated unemployment rate of only 0.3 percent. By themselves, very low unemployment rates are evidence more of the general employability of scientists and engineers than of generalized shortages. Other information is needed to identify fields with insuffcent supplies.

2. *Reported Job Openings*

NSF staff have asked employers of scientists and engineers about the difficulty they have experienced in filling job vacancies. In mid-1979, 27 large industrial companies and research laboratories responded to an NSF survey on this subject. All industrial employers who reported about engineers and computer professionals said that both categories were in short supply. Supporting evidence of shortages of engineers came from the Engineering Manpower Commission,[5] the College Placement Council,[6] and the National Research Council.[7] The U.S. Department of Labor's designation of several engineering subfields as "hard-to-fill occupations" also indicates shortages. Employers in the industrial sector indicated generally ample supplies of physicists, biologists, chemists, and mathematicians, though (as already noted) spot shortages are reported in several subspecialties.[8]

In correspondence with representatives of schools of engineering and departments of computer science in 1979, NSF staff have found widespread expressions of severe difficulty in finding doctoral faculty. The large numbers of vacancies reflect not only the generally tight markets in these fields, but also the disadvantage of universities in competing with industrial employers who pay much higher salaries and who frequently offer superior facilities and research support to doctoral engineers and computer professionals. Contributing to the shortages of engineering faculty was a drop in doctoral awards in this field of 25 percent (3338 to 2494) between 1973 and 1979. In the latter year, approximately one-third of the new Ph.D.'s were nonimmigrant foreign students.[9]

Short papers contributed by several Federal agencies for this study contained similar reports of the tight market for engineers. In the defense agencies, problems in recruiting and retaining both civilian and military engineers are aggravated by low starting salaries, low promotion rates, and often outmoded facilities for research and development. The Department of Energy stresses the need for engineers, particularly at the advanced degree level, to carry out research and development for the Nation's synthetic fuel program (Appendix D-4).

Two indicators—changing relative salaries (3. below) and patterns of mobility between fields of training and fields of employment (4. below)—provide evidence of the adjustments made by labor markets to alleviate shortages and surpluses.

3. *Salary Data*

Economic theory predicts that salaries in a field with shortages, or high demand, will rise relative to salaries in nonshortage fields. Salaries for new employees are more flexible than are those for experienced workers and, therefore, reflect changes in market conditions more closely. From 1974 through 1979, according to data from the College Placement Council, starting salaries for baccalaureate computer professionals and chemical, electrical, and mechanical engineers rose from 53 to 58 percent as compared to 37 and 42 percent rises for bachelor's degree holders in business and the humanities, respectively.[10] These data also indicated a 51 percent increase in salaries for mathematics and chemistry baccalaureates and a 41 percent increase for those with degrees in biology, 38 percent for the social sciences, and 33 percent for the agricultural sciences.

4. *Field Mobility Measures*

Many new graduates, at all degree levels, choose to enter fields different from those in which they were educated. Such mobility across disciplines reflects market conditions in the chosen field of employment relative to the field of training as well as personal preferences. The ratio of the number of science and engineering graduates who enter the labor force in a particular field to the number earning degrees in the same discipline is an indicator of that field's balance between the supply of graduates and the demand for new workers, as well as the ease of transferring between fields. By this measure, there has been a marked shortage of degree recipients in the computer professions.

An NSF survey found that there were 2.7 times as many 1977 baccalaureates working in the computer professions in 1979 as had earned bachelor's degrees in that field two years earlier.[11] At the master's degree level, the ratio was 1.6. These figures are the result of many 1977 science and engineering graduates in other fields switching to exploit superior job opportunities in the computer profession. (These two figures as well as those below were adjusted to exclude those engaged in full-time graduate study in 1979.) In engineering and chemistry, the corresponding ratios were all near 1, indicating strong markets in those two fields. By contrast, the following pairs of ratios for bachelor's and master's recipients were found in other fields: physics, .3 and .3; mathematical sciences, .2 and .4; environmental sciences, .5 and .8; biology, .3 and .6; psychology, .1 and .5; and economics, .2 and .6. (In these other fields, a master's degree is often the minimum educational requirement so the very low ratios at the baccalaureate level may overstate the relative lack of attractive job opportunities.) At the doctoral level, the most marked field switching has been to the computer professions. In 1979, about 3.5 times as many Ph.D.'s worked as computer professionals as had ever earned degrees in the field. The largest relative exodus occurred from physics and astronomy, which had only about 70 percent as many working in those fields as had earned degrees in them.

B. Projected Supply and Demand for Scientists and Engineers in 1990

Projections of the future balance between the supply of and demand for scientists and engineers point out those fields in which shortages of science and engineering personnel may prevent the U.S. from meeting important national goals. If projections indicate potential shortages, a decision can be made about whether the Federal Government should intervene to prevent the projected shortfall. Because of the length of time required to train scientists and engineers, efforts to increase supply can only have an effect after several years—hence the need to anticipate shortages well before they occur.

Summary of Projections

The projections described below indicate that in 1990 the supply of scientists and engineers at all degree levels will likely be more than adequate to meet demand in all fields except the computer professions, statistics, and some fields of engineering. These projections are summarized in Table I.

In general, the number of new science graduates should widely exceed the number who will be able to find jobs in the disciplines in which they were trained. The projected excess of graduates over jobs implies many with science degrees will take employment not directly related to science and engineering. Also implied is a continued upgrading of the level of training of the technical labor force. Baccalaureates would fill jobs once held by high school graduates and doctorates would fill positions formerly held by those with less training, often in positions unrelated to teaching or research and development.

These projections indicate that for engineers with bachelor's or master's degrees, the labor market in 1990 should be less tight than at any time since the early 1970s as a result of faster expansion in the supply of qualified personnel than in demand for their services. Employers may have difficulty, however, in finding graduates in some fields of engineering, such as aeronautical and industrial, particularly if defense programs expand rapidly.

Two sets of projections, one prepared by the Bureau of Labor Statistics, the other by the National Science Foun-

Table I
Projected Market For Scientists and Engineers in 1990 by Field and Level of Training
(all scenarios)

	Baccalaureates and Masters	*Doctorates*
Physical Sciences	Adequate	Adequate
Atmospheric	Balance	
Chemical	Adequate	
Geological	Adequate	
Physics and Astronomy	Adequate	
Engineering	Adequate	Uncertain (Possible shortages some fields)
Aeronautical	Balance-Shortage[1]	
Chemical	Adequate	
Civil	Adequate	
Electrical	Adequate	
Industrial	Shortage	
Mechanical	Adequate	
Metallurgical	Adequate	
Mining	Adequate	
Petroleum	Balance	
Other	Adequate	
Mathematical Sciences	Adequate	Adequate
Mathematicians	Adequate	
Statisticians	Shortage	
Computer Professions	Shortage	Shortage
Life Sciences	Adequate	Adequate
Agricultural	Adequate	Adequate
Biological	Adequate	Adequate
Social Sciences	Adequate	Adequate
Psychologists	Adequate	
Other	Adequate	
All Fields	Adequate	Adequate

[1] Shortage under expanded defense spending assumption only.

NOTE: "Adequate" indicates that projected supply exceeds projected demand. "Balance" indicates that projected supply is close to projected demand. "Shortage" indicates that projected supply is less than projected demand. "Uncertain" is used for doctoral engineers because NSF projects an adequate supply in 1990 whereas BLS projects a shortage in 1985.
SOURCES: Bureau of Labor Statistics, National Center for Education Statistics, and National Science Foundation.

dation, differ as to whether in the future there will be an ample supply or a shortage of doctoral engineers.

Some general limitations of all supply/demand projections are discussed in Section II-C (below). None of these is believed to invalidate the key projection findings summarized in Table I. However, it is worth noting at the outset that the supply projections (discussed in detail below and in Appendix A) assume that colleges and universities will have the capacity to educate all students at both the undergraduate and graduate levels who want to obtain degrees in a particular field of science or engineering and who are judged by those institutions to be qualified to do so. Several critics have suggested that this assumption may be unwarranted for engineering colleges. They point to several factors discussed in more detail in Section III-B—rising undergraduate enrollments, falling levels of Ph.D. production, and faculty shortages indicate that these colleges may not be able to train all qualified applicants.[12] In this case there would be fewer engineers available in 1990 than the projections indicate, possibly resulting in continuing tight markets in most specialties and, perhaps, serious personnel shortages in a few of them.

Projected 1990 Supply and Utilization of Scientists and Engineers

With the combined efforts of three agencies—the National Science Foundation (NSF), the Bureau of Labor Statistics (BLS), and the National Center for Education Statistics (NCES)—projections have been prepared of the supply and employment of all scientists and engineers in 1990. In recognition of the leadership provided by Ph.D.'s in teaching, research, and management, additional projections describe possible conditions in the 1990 science and engineering doctoral labor market.

1. *All Scientists and Engineers*

The Bureau of Labor Statistics has developed two sets of projections of the demand for scientists and engineers at all degree levels in 1990. These projections (a Technical Note in Appendix A describes BLS projection methods) were carried out in a series of steps linking expected aggregate economic activity to output by industry to employment by occupation. BLS produced the first, or baseline, set of projections in 1979. These projections start with a set of assumptions covering the nature of economic conditions and Federal policy goals during the 1980s. These assumptions include a decline in unemployment to 4.5 percent by 1990 and an annual increase in labor productivity to 2.4 percent by 1985–1990 *above* the current rate. The policy goals in the baseline projections do *not* include (1) a sharply augmented defense budget; (2) large-scale development of synthetic fuels; or (3) a balanced Federal budget.

To assess the sensitivity of the baseline demand projections to alternative assumptions, BLS developed a set of alternative projections in which each of these three policy goals was included one at a time. This procedure allowed an estimation of the impact of each goal upon the utilization of scientists and engineers. These assumptions represent fairly extreme conditions. For example, the greatly expanded expenditures for defense would be in a scientific and technologically intense sector and would not be compensated for by decreased nondefense expenditures. It should be noted that these projections do not include scientists and engineers employed by secondary schools, colleges, and universities, since BLS does not project employment in educational institutions by field. The omission of academic employment in aggregate projections is mitigated by its inclusion in the projections of Ph.D. utilization (as described below), since Ph.D.'s account for a large majority of those employed in higher education.

Under the baseline assumption, BLS projects that the employment of scientists and engineers in science and engineering occupations and at all degree levels will grow by about 40 percent between 1978 and 1990. This growth would create about 180,000 new jobs in the mathematical, physical, life and social sciences, about 480,000 new jobs in the computer professions, and 250,000 new engineering jobs during the twelve-year period.* By far the most rapid growth, about 110 percent, is projected for computer professionals. Employment of all engineers combined is projected to grow by less than 25 percent, with the most rapid expansion for mining (almost 50 percent) and petroleum engineers (40 percent). Estimated growth in all other major subfields ranges between 19 and 28 percent. It should be noted that many computer professionals obtain their degrees from electrical engineering departments. If demand for these categories of computer professionals were combined with electrical engineering, employment in the latter specialty would be projected to grow at a much greater rate.

Among the sciences, growth is put at 40 percent for psychologists, geologists, statisticians, and economists. Occupations with projected slow growth include atmospheric scientists, physicists and astronomers, and mathematicians, all of which are projected at 10 percent or less.

Under the baseline assumption, defense expenditures (excluding compensation of military personnel) rise by 14 percent, or $6 billion in 1972 dollars, between 1978 and 1990. The assumption of a more rapid expansion of 43 percent, or $18 billion in 1972 dollars, has a small effect upon projected employment except for aeronautical engineers. Under this assumption, requirements for aeronautical engineeers would expand by about 40 percent over the twelve-year period, or double the baseline expansion.

To assess the possible impact of a second goal upon the science and engineering labor market in 1990, BLS, after consulting with the Department of Energy, devised a hypothetical program for the construction and operation of new facilities for coal liquefaction and gasification and oil shale development. The program, which is not intended to

* New jobs created by growth plus openings for existing positions created by attrition of currently active workers equal total job openings reported in Table II.

represent any official Administration proposal for synthetic fuels production, would produce about three quadrillion BTU's. This would be about three percent of the total energy supply, including imports, projected by BLS to be available in 1990, and equivalent to 1.4 million barrels of oil per day (MMBPD). In contrast, the recent House-Senate conference synthetic fuels bill sets a 1987 goal of 0.5 MMBPD and a 1992 target of 2.0 MMBPD.

BLS projections indicate that a synthetic fuels program of the scale analyzed would have only a very small effect upon science and engineering employment in 1990 and would not alter the market assessments made under the baseline projections. In assessing the effects of a large synthetic fuels program, BLS assumed that existing technology would be used in production facilities installed over the next ten years. As a result, most additional employment would be devoted to the construction and operation of new plants. These two activities require only limited numbers of scientists and engineers.

A final alternative projection assumes that the Federal budget will be in approximate balance by 1983 and will continue to be so through 1990. This is in contrast to the baseline assumption that the Federal budget will have a $32 billion deficit in 1980 that will decline to a $23 billion deficit in 1990. The alternative assumption of a balanced budget, achieved through higher taxes and lower expenditures, has no major effect upon projected 1990 science and engineering employment, since the assumed changes in fiscal policy would affect the economy as a whole and have relatively little effect on those industries with high concentrations of scientists and engineers.

The demand for new science and engineering graduates between 1978 and 1990 was derived from estimates of 1990 employment. This demand would be for trained but inexperienced workers to replace experienced personnel who would die or retire and to fill the new jobs created in the twelve-year period. Under both the baseline and alternative assumptions, about 360,000 scientists and over one million computer professionals and engineers, or a total of about 1.4 million scientists and engineers would be needed to fill growth and replacement demand (excluding openings in academia). These estimates of employment openings by occupation are compared in Table II with projections by NCES of the supply of graduates at the baccalaureate and master's degree levels through 1990 in each field. NCES projects that there will be about 3.4 million science and engineering baccalaureates and 630,000 science and engineering master's degrees awarded between 1978 and 1990 in the fields considered here. (A Technical Note in Appendix A describes NCES projection methods.)

Table II provides comparisons of BLS and NCES projections by field. These comparisons point to two fields with large deficits of people with bachelor's and master's degrees: the computer professions and statistics. Such gaps would be expected to attract large numbers of people with training in other fields, particularly mathematics, where degrees are expected to be many times larger than job openings. Such inter-field mobility would continue the patterns of recent years. It is expected that such field-switching would prevent the emergence of a tight market for statisticians and would greatly diminish shortages of computer professionals. Other fields with large projected surpluses of graduates are agricultural sciences and natural resources, biology, physics and astronomy, psychology, and, as a group, the major social sciences. Baccalaureate chemists will also far outnumber jobs although supply may be fairly close to demand for master's degree holders in the field.

In all engineering fields, projected baccalaureates, including those in engineering technology, are almost 1.8 times the projected baseline openings. (Supply projections assume that engineering colleges will be able to expand enrollment significantly beyond current levels.) Under the baseline projections, only industrial engineers may have fewer graduates than openings. An accelerated defense program may push aeronautical engineers into a small 1990 deficit. Nuclear engineeers, a small subfield for which BLS did not prepare separate projections, may also have future shortages, according to the Department of Energy, because many universities have eliminated their nuclear engineering departments and more are scheduled to do so.[13] Finally, since many new engineers are likely to continue to seek nonengineering jobs due to their own preference, the engineering labor market in 1990 may be tighter than the numbers in Table II would indicate.

A separate study supported by the Department of Agriculture considered current and future supply and demand in many occupations other than agricultural science (the only related occupation for which BLS and NCES projections have been compared here) for which agricultural or natural resources training may be required. The Agriculture study found that in 1985 there may be shortages of workers with training in several job categories such as agricultural engineering and food and agricultural chemistry.[14]

2. *Personnel Requirements under National Energy Scenarios*

Several studies commissioned by the Federal Government have projected requirements for technical personnel under various national energy scenarios. Three studies have explored the personnel implications of large-scale programs to substitute synthetic fuels for imported oil and one has assessed the future adequacy of personnel supply in the coal mining industry. These studies are reviewed below.

a. The earliest and most comprehensive of the four studies was completed under an NSF contract in mid-1977 by the Center for Advanced Computation (CAC) at the University of Illinois. For this study, *Scientific and Technical Personnel in Energy-Related Activities: Current Situation and Future Requirements,* CAC combined its own highly disaggregated model of the energy sector with the BLS employment projection model. This allowed CAC to project requirements for scientists and engineers in 1980 and 1985 for the entire economy under three scenarios. This is in contrast to the other three energy-related studies which looked only at the energy-production sector. CAC describes the three scenarios as quoted below.

The Free Import Scenario assumes that energy consumption in the United States increases from the 1973 level of about 73 quadrillion Btu's to 99.1 quadrillion Btu's in 1985. Domestic energy production increases, but the growth of imports of oil and gas are substantial.

The Limited Imports Scenario assumes energy usage increases to 84.1 quadrillion Btu's in 1985. Domestic coal production increases substantially more than in Free Imports and nuclear power grows substantially more. Oil imports are much lower under Limited Imports.

The Synthetics Scenario uses the same major assumptions as the Limited Imports Scenario but in addition assumes a program of developing synthetic oil and gas that would produce a .9 MMBPD (million barrels per day) oil equivalent in 1985 and 1.8 MMBPD equivalent in 1990. The

Table II
Comparisons of Projected Job Openings With Projected Degrees in Science and Engineering 1978–1990

	Job Openings, 1978–1990 (in thousands) Scenario				*Graduates, 1978–1990 (in thousands) Level*	
	Baseline Assumptions	*Accelerated Defense Spending*	*Synthetic Fuels Program*	*Balanced Federal Budget*	*Baccalaureate Degrees*	*Master's Degrees*
Life and Physical Scientists						
Agricultural	16	16	16	16	193	34
Atmospheric	5	5	5	5	5	4
Biological	38	38	38	37	637	78
Chemical	63	64	64	63	178	26
Geological	22	22	23	22	67	18
Marine	2	2	2	2	10	3
Physics and Astronomy	11	11	11	11	45	19
Total	157	159	157	156	1,135	182
Mathematical Sciences						
Mathematicians	3	3	3	3	102	27
Statisticians	19	19	19	19	3	5
Total	22	22	22	22	105	32
Computer Professionals						
Programmers	300	302	300	299	NA	NA
Systems Analysts	221	223	221	221		
Other	28	29	28	28		
Total	549	553	550	547	110	47
Social Scientists						
Psychologists	76	76	76	75	490	111
Other[1]	100	102	101	99	628	58
Total	176	178	177	175	1,117	170
Engineers						
Aeronautical	24	35	24	24	28	NA
Chemical	22	22	22	21	92	
Civil	95	95	95	94	134	
Electrical	121	128	121	120	172	
Industrial	94	98	94	93	48	
Mechanical	89	95	89	89	171	
Metallurgical	9	9	9	9	16	
Mining	7	7	7	7	11	
Petroleum	11	11	11	11	14	
Other	59	61	59	59	115	
Total	528	561	534[2]	525	928[3]	196
Total all Fields	1,432	1,473	1,439	1,424	3,395	626

[1] Includes economists, political scientists, and sociologists.
[2] Includes 4,000 engineers who are not distributed by field.
[3] Includes 128,000 engineering technology degrees not distributed by field.
NOTE: Estimates of openings do not include academic employment. Detail may not add to totals because of rounding.
SOURCES: National Science Foundation, Bureau of Labor Statistics, and National Center for Education Statistics.

1985 output is assumed to be .3 MMBPD of shale oil, .1 MMBPD of coal liquids, .3 MMBPD of high-Btu gas, and .3 MMBPD of low- and medium-Btu gas from coal (pp. 125–126, CAC report).

CAC found that, for the economy as a whole, the three scenarios differed little in their requirements for scientists and engineers in 1985. Moreover, the differences were "in a direction that is counterintuitive." CAC found that the "Free Imports" scenario had slightly greater personnel requirements. CAC explained that "Free Imports" had the highest level of energy consumption of the three scenarios and hence the highest employment for energy production. This difference outweighed the higher construction employment under "Limited Imports" and "Synthetics" (p. viii). (It should be noted that Bechtel National, which prepared another study reviewed below, provided CAC the estimates of direct requirements for personnel for construction under the three scenarios.)

In 1979, the Department of Energy (DOE) commissioned four studies to assess the feasibility of a national program to produce 1.0 MMBPD of oil through coal liquefaction by 1990. For two studies, contractors, Bechtel National and UOP working with System Development Corporation (UOP/SDC), examined whether the lack of skilled manpower, particularly engineers, would impede meeting this goal. All four studies are summarized and presented as appendices in a March 14, 1980 TRW draft report to DOE, *Achieving a Production Goal of 1 Million B/D of Coal Liquids by 1990*.

Bechtel and UOP/SDC both assessed material and manpower requirements under current liquefaction technology. Bechtel analyzed engineering demand by subfield, chemical, mechanical, etc., whereas UOP/SDC examined all "technical manpower" together. Also, Bechtel considered requirements for both construction and operation of liquefaction plants whereas UOP/SDC, which was concerned with the chief potential impediments to meeting the synthetic fuels goal, examined only construction employment.

b. In *Production of Synthetic Liquids from Coal: 1980–2000*, Bechtel states that the supply of civil, electrical, industrial, and mechanical engineers "should be adequate" to meet the 1990 production goal (p. 4-8) although there could be major difficulties in sufficiently expanding the employment of chemical engineers. Bechtel calculates that the stated goal could require a peak of 1300 additional chemical engineers by 1984 (p. 4-4). For comparison, this would be about two to three percent of the 1978 stock of chemical engineers and about 13 percent of the latter who are engaged in "process design and construction work" (p. 4-7).

In evaluating the Bechtel findings, it is evident that coal liquefaction of one MMBPD by 1990 might cause some labor market adjustments. These might be reflected in such developments as experienced engineers being bid away from other jobs to the synthetic fuels program and in inexperienced graduates being asked to assume greater responsibilities more quickly than might normally be the case. Such adjustments, however, are clearly to be expected whenever any industry rapidly expands its level of production. Only industries with large excess capacities can assume major new roles without introducing short-term dislocations in skilled labor markets.

c. In *Feasibility Appraisal: Production of Synthetic Fuel from Direct and Indirect Coal Liquefaction Processes*, UOP/SDC examined four different technical processes for producing 1.0 MMBPD by 1990. This DOE-contracted study found that only one, liquefaction through the "methanol-gasoline" approach, would require more than 20 percent of the technical personnel, including engineers, employed by the firms capable of constructing liquefaction plants. This meant to UOP/SDC that the three other approaches, as well as an equally proportioned mix of all four techniques, would keep technical personnel requirements in construction firms below the "danger point" (p. 6-68B).

d. The synthetic fuels scenarios discussed above would, if implemented, all require massive increases in domestic coal production. Under a DOE contract, The MITRE Corporation prepared the 1980 report, *Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000*. For this study MITRE developed a projection model which combined systems dynamics and econometric techniques. This allowed an analysis of personnel supply and demand based on interrelationships between technological change, labor productivity, production costs, wages, graduation rates, and other key variables. MITRE found that a shortage of mining engineers was unlikely by the mid-1980s. Only under a combination of extreme circumstances would shortages appear (Executive Summary, p. 4). MITRE, however, warned that there is currently a shortage of mining and mineral engineering faculty.

Based upon the above analysis of these reports, it is concluded that these studies are consistent with the earlier statement that "a synthetic fuels program of this scale would have only a very small effect upon science and engineering employment in 1990 . . ." The supply of engineers should be generally adequate to produce 1.0 MMBPD by 1990, although there may be short-term dislocations in some engineering fields, particularly chemical engineering.[15]

The Department of Energy is less optimistic on the subject of technical personnel available for the synthetic fuel industry, noting that the synthetic fuels program will place an early peak load on engineering capacity and will have to be carried out by engineers who are now active (Appendix D-4). Some of these engineers will have to be enticed away from other sectors of the economy which, in the opinion of DOE, could cause major dislocations in those sectors. DOE's Office of Energy Research has recently been given responsibility for energy-related personnel assessments, and plans to pursue a number of technology-specific projections during the next few years.

3. *Doctoral Scientists and Engineers*

Projections prepared by the National Science Foundation in 1978 (the methodology is described in a Technical Note in Appendix A) estimated that there would be more than enough Ph.D.'s through 1987 to fill available jobs at that level in four broadly defined fields: the mathematical, physical, life, and social sciences. These projections also indicated that there would be more than enough engineering Ph.D.'s in 1987.[16] These NSF doctoral projections were extended to 1990 for the purposes of the present review. The 1990 projections indicate that an increasing percentage of science and engineering Ph.D.'s are likely to be employed in jobs that are not directly related to science and engineering. (According to a recent NSF study, many Ph.D.'s enter such employment because of their own preference.[17]) Results of these Ph.D. projections are summarized in Table III.

The general findings of the NSF analysis for the four broad scientific fields are very similar to 1985 Ph.D. projections made by BLS in 1978. The two sets of projections differ, however, for engineering, where BLS foresees a Ph.D. shortage.[18] Because the NSF projections did not account for the continued strong market for B.S. engineers, they may have overestimated future graduate engineering enrollments and, hence, future doctoral supply. If so, the market for Ph.D. engineers may remain tight through 1990.

It should be noted that computer professionals are included under the mathematical sciences in these projections, even though (as already discussed) many receive degrees from engineering departments. Available evidence on current graduate enrollments and industrial demand suggests that computer professionals at the Ph.D. level will be in short supply through 1990.[19]

C. Limitations of Projections

Projections are useful for making general assessments of the future adequacy of the science and engineering labor force. For this purpose they are subject to limitations stemming from two chief sources. The first type of limitation is generic to all projections. It is caused by the impossibility of predicting all the events that may affect whatever is being projected, in this case the supply and utilization of scientists and engineers. The second type, which affects primarily the supply projections, results from an incomplete understanding of how students choose careers and how the science and engineering labor markets function.

In regard to the first type, uncertainties associated with national and world economic conditions can have major, unanticipated effects on science and engineering labor markets. For example, the demand for and price of particular goods and services might shift significantly, thereby shifting demands for all workers, including scientists and engineers.

The emergence of new technologies is another important factor which can have a potential influence on science and engineering labor markets. It may affect employment either

Table III
Full-Time Science and Engineering Doctoral Labor Force by Field
1979 Actual and 1990 Projected
(in thousands)

	Physical Sciences	*Engineering*	*Mathematical Sciences*	*Life Sciences*	*Social Sciences*	*Total*
Labor Force						
1979	73	49	21	79	83	306
1990	103	80	30	113	125	450
Science/Engineering Utilization						
1979	67	47	20	74	71	278
1990	93	63	23	93	99	370
Non-Science/Engineering Utilization						
1979	7	3	1	5	12	28
1990	10	17	7	20	26	80
Non-Science/Engineering Utilization as Percent of Labor Force						
1979	9	6	6	6	14	9
1990	10	21	23	18	21	18

NOTE: Detail may not add to totals because of rounding.
SOURCE: National Science Foundation.

by offering ways of more efficiently producing existing goods or services or through the introduction of new goods or services. To exploit these technical innovations, occupational specialities that do not now exist may emerge or openings in existing occupations may grow or decline unexpectedly. Thus technological change may cause market imbalances that cannot be foreseen when projections are made.

With regard to the second type of limitation, the NCES projections of baccalaureate and master's degree recipients do not account for how the market leads students into those fields with shortages and away from fields with poorer job opportunities. Therefore, the projections of new graduates, except at the doctoral level where adjustments are made by NSF for market effects, have a tendency to overstate both future shortages and surpluses. Also, current methods of projecting supply can make only crude adjustments for the widespread flow of students from the fields of their training to the other fields where they choose to work. These flows are often substantial when fields differ greatly in their relative balances between supply and demand. Additionally, forecasters are unable to predict how factors, such as public opinion about the role of science and technology in society, may affect the flows of new graduates.

Finally, the projections of engineering graduates presented in this report assume that engineering schools will be able to expand their enrollments sufficiently to meet projected class sizes. Some specialists question the validity of this assumption.[20] Several reviewers also believe that the current excess demand for computer professionals and engineers is likely to continue and may become more severe.[21]

In sum, such projections are adequate to the extent that assumptions are accurate and past trends continue; they cannot anticipate unforeseen structural breaks with past trends. However, we believe the general conclusions of this analysis stand in spite of these limitations and possibilities. They are based on such wide differences between projected graduates and job openings that only very large projection errors could invalidate them. In summary, the main points are: (a) in 1990 the demand for computer professionals is likely to be greater than the supply of those trained in the field; (b) the labor market for a few categories of engineers should not be tight; and (c) the supply of scientists in all broadly defined fields should exceed requirements.

D. Quality Considerations

Assessments of the qualitative adequacy of the Nation's science and engineeering labor force necessarily require references to a set of norms. Examples of norms might include statements such as: (a) all college majors in science and engineering should be drawn from the top 15 percent of their high school class; (b) all college and university science and engineering faculty should have Ph.D. degrees; or (c) all personnel who enter science and engineering occupational specialties should have degrees in those specialties. In one sense, the quality of our science and engineering labor force can never be completely adequate because the Nation can always benefit from an improvement in the training and ability of science and engineering teachers, researchers, and other workers. Thus, any evaluation of the qualitative adequacy of the supply of scientists and engineers should be constrained by a recognition of the competing claims from other sectors of society for highly qualified people, the costs of training scientists and engineers, and the possible personal costs to those who regard themselves as underemployed, because they are not working in fields or specialities for which they were trained.

No indicators are available to measure or predict the future quality of American scientists and engineers. However, we do know a great deal about past U.S. scientific accomplishments. In the 35 years since the end of World War II, this country has established and maintained preeminence in many fields of knowledge. Evidence of U.S. scientific and technological leadership is found, to cite a few examples, in the record of the manned space-flight program, the continuing dramatic improvement in computer engineering, breakthroughs in our understanding of genetic processes, and new insights into the fundamental structure of matter. In recognition of pioneering work such as that cited above, American scientists and engineers have won 51 percent of the Nobel Prizes, excluding the prizes for peace and economics, awarded in the post-World War II period. Publication activity and citation analyses provide additional evidence of the past high level of productivity of U.S. scientists and engineers.

On the negative side, several indicators point to a relative decline in the technological advantage of U.S. industry compared with its foreign competitors. These indicators include relative changes in labor productivity and relative numbers of U.S. patents granted to U.S. and foreign applicants. No proven relationships exist between the quality of the science and engineering labor force and industrial productivity, though there are correlations, at least, between productivity and rates of research and development investment. However, it is at least plausible that the level of technical competence of all workers in an industry, *including* scientists and engineers, bears directly on the problem of improving industrial productivity. If so, then the qualifications of students who intend to enter science and engineering occupations are germane to the broad question of the adequacy of science and engineering education for long-term national needs.

Although it is clear that the current U.S. technical labor force contains a large share of the world's most productive scientists and engineers, some observers question whether the U.S. will be able to sustain this level of quality. Some of these observers maintain that the most able students are turning away from science and engineering to careers such as business, law, and medicine. Evidence suggests that such a sharply negative appraisal is not warranted.

The percentage of the science and engineering labor force holding doctoral degrees is one indirect measure of the ability of the U.S. to compete scientifically. A labor force better educated in science and engineering is better prepared to remain abreast of rapidly expanding scientific knowledge and to explore new areas of exceptional opportunity, such as recombinant DNA research. From 1973 to 1979 the number of active science and engineering doctorates expanded from 223,000 to 317,000, or 42 percent. The rising extent of advanced education among mathematical, physical and life scientists was marked by a doubling between 1960 and 1978 of the proportion of Ph.D.'s in the natural sciences labor force.

According to two indicators of the academic ability of young people planning science and engineering study, many able graduates will continue to join the science and engineering labor force during the 1980s. One of these indicators reflects the general scholastic capacity of future scientists and engineers as they prepare to enter graduate school. Another indicator is the record over the past 14 years of the college study plans of those high school students selected as being the most capable in each year's graduating class.

The large majority of applicants to graduate school take the Graduate Record Examination (GRE) during their junior or senior year in college. Over the eight-year period ending in 1978, the test scores of prospective science and engineering graduate students on the quantitative components of the GRE remained high and unchanged both in absolute terms and relative to the average scores of graduate students in nonscience fields.[22] In particular, candidates for graduate study in the physical sciences, mathematics, and engineering scored much higher on average than did those planning nonscience and nonengineering study. Undergraduates applying for admission to graduate life sciences programs scored well below the levels of candidates in the three fields above but still well above the average for nonscience and nonengineering applicants. On the verbal portion of the GRE, science and engineering applicants averaged about the same as did those applying for study in other fields.

Each year the National Merit Scholarship Corporation selects about 14,000 high school seniors as being the most gifted academically in the Nation. From these finalists, a fraction—about one-third in 1979—are chosen to receive Merit Scholarships. In each year from 1966 to 1979 at least 41 percent and as many as 49 percent of the scholarship winners indicated plans to major in engineering, the natural sciences, or mathematics, including computer science.[23] These figures do not include those planning preparatory programs for the health professions or prospective social science majors. The larger group of finalists has had similar plans. In 1979 about 26 percent of both winners and finalists planned majors in the sciences and about 20 percent planned to study engineering. Although many high school seniors earn degrees in fields different from those which they indicate on entry into college, science and engineering continue to be attractive to many of the best students entering college each year.

These indicators apply only to students who are contemplating careers or at least majors in science and engineering fields. Broader assessments of the educational attainments of all high school students suggest that the science and mathematics competence of those who do not intend to pursue serious study in these fields has declined considerably since the early 1960s. These assessments are discussed in Section V-B.

In addition, indicators of the qualifications of students who enter college intending to pursue science or engineering majors or of those who enter graduate school in those fields provide no information about the adequacy of the education they receive in those institutions. A full assessment of the adequacy of professional science and engineering education would of necessity require reference to present and future expectations of prospective employers. However, even in the absence of such information, there are indications that the U.S. higher education system is under considerable strain and is not able to provide as high quality education in science and, more particularly, in engineering as many specialists believe it could.

References

1. National Academy of Engineering Task Force on Engineering Education. *Issues in Engineering Education: A Framework for Analysis.* Washington, D.C.: National Academy of Engineering, 1980, pp. 15–16.

Paper submitted by the American Society for Engineering Education (Appendix D-2).

This point was also emphasized by several evaluators of a draft of this review, including Donald Glower (The Ohio State University), Donald Marlowe (American Society for Engineering Education), and F. Karl Willenbrock (Southern Methodist University).

2. Current spot shortages in industry in several engineering fields and in scientific subdisciplines were reported by participants in National Research Council Seminars V-A and B (Appendix E). Their existence was also noted by several evaluators of an early draft of this review, including Lewis Branscomb (International Business Machines Co.), William Hubbard (The Upjohn Co.), and J.E. Stevenot (Procter and Gamble Co.).

3. National Council of Teachers of Mathematics, Press Release, October 19, 1978, Reston, VA.; B.G. Aldridge, "Announcement of Results of the National Science Teachers Association Survey (1980)." Washington, D.C.: NSTA.

4. NSF Division of Science Resources Study (unpublished report). *Employment and Training Report of the President, 1979.*

5. Engineers Joint Council, Engineering Manpower Commission. *Placement of Engineering and Technology Graduates, 1979.* New York, October 1979.

6. A June 17, 1980 news release from the College Placement Council (Bethlehem, PA) notes that the number of job offers to new engineering baccalaureates has increased by 21 percent since June 1979.

7. National Research Council Seminar IV-B (Appendix E).

8. *op. cit.*, Note 2.

9. Based on data in recent annual issues of *Summary Report, Doctoral Recipients from U.S. Universities*, published by the National Research Council.

10. College Placement Council. *Salary Survey-Final Report.* Issued annually from Bethlehem, PA.

11. College Placement Council, Bethlehem, PA. Unpublished survey.

12. *op. cit.*, Note 1.

13. Comment on early draft of this review by James G. Ling, Department of Energy.

14. Office of Higher Education, U.S. Department of Agriculture, "Report of Manpower Assessment Project," 1980 (unpublished).

15. The existence of shortages of chemical engineers was cited by Lewis Branscomb (International Business Machines Co.) and J. E. Stevenot (Proctor and Gamble Co.) in critiques of an early draft of this review.

16. National Science Foundation. *Projections of Science and Engineering Doctorate Supply and Utilization: 1982 and 1987*. NSF Report # 79-303.

17. National Science Board. *Science Indicators, 1978*. Washington, D.C.: U.S. Government Printing Office, 1979, p. 119 (Table 5-2).

18. Douglas Braddock. "The Oversupply of Ph.D.'s to Continue Through 1985." *Monthly Labor Review*, October 1978, pp. 48–50.

19. According to the National Center for Education Statistics, Ph.D.'s in computer science grew from 107 in 1970 to 196 in 1978. Such growth in new graduates is not expected to be sufficient to meet the anticipated rapid expansion in industrial and academic demand for doctorates in this field. See also Jerome A. Feldman and William R. Sutherland. "Rejuvenating Experimental Computer Science." *Communications of the ACM* v. 22, #9. Sept. 1979, pp. 497–502.

20. *op. cit.*, Note 1.

21. Several persons expressed this belief in assessments of an early draft of this review. They include Kenneth Baker (Harvey Mudd College), Lewis Branscomb (International Business Machines Co.), Donald Glower (The Ohio State University), John Whinnery (University of California, Berkeley), and F. Karl Willenbrock (Southern Methodist University).

22. *op. cit.*, Note 17, pp. 125–129.

23. National Merit Scholarship Corporation, *Annual Report* (issued yearly).