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ABSTRACT

This report presents findings of a special analysis designed to project science, engineering, and technician (SET) personnel requirements of both defense and nondefense sectors during the 5-year period ending in 1987 and to assess the projected supply of such personnel available to meet those requirements. Following an introduction, the report is organized into two main sections. The first section provides an overview of the Interindustry Forecasting System (IFS) that was used to generate employment projections of SET personnel. It presents pertinent assumptions underlying four scenarios chosen for analysis, and reports total and defense-related employment requirements through 1987. These requirements are presented separately for scientists (computer systems analysts and social, physical, mathematical, and life scientists), engineers (electrical/electronic, mechanical, aeronautical/astronomical engineers), and technicians (computer programmers, drafters, and science and engineering (SE) technicians). The second section describes the DauffenBach/Fiorito/Folk (DFF) labor supply model, presents information on the importance of various components of the SE labor supply, and provides comparisons of demand and supply projections to assess potential labor market balance. An assessment of projected labor market balance for SE-support technicians is also presented in this section. Information on the IFS and DFF models and supporting data (presented in 20 statistical tables) are included in appendices. (JN)

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foreword

The decade of the eighties has been characterized by a growing concern about the condition of this country's technological resources. Programs to promote basic research, to reassess research and development priorities, and to improve the quality of science and engineering education, are just a few initiatives that clearly demonstrate the strong commitment being made by Government, industry, and academia in this area. This commitment is founded on the continuing role of high technology in promoting economic growth, productivity, and international competitiveness. Over the next several years, this same technology will be called on to help meet the goals of the Nation's 5-year defense plan. In fiscal year (FY) 1983, this plan scheduled an increase in real defense expenditures of almost 45 percent over the 1982-87 period. Proposed defense budgets for FY 1984 and FY 1985 show similar emphasis. Highly trained science, engineering, and technician (SET) personnel are essential to these industries and, hence, the Nation's ability to meet both overall economic- and defense-related objectives.

This report presents findings of a special analysis undertaken by the National Science Foundation (NSF). The objectives of the study are twofold: First, to project SET personnel requirements of both defense and nondefense sectors during the 5-year period ending in 1987, second, to assess the adequacy of the projected supply of such personnel available to meet those requirements. Employment projections for the study were generated through the use of the Defense Interindustry Forecasting System developed by Data Resources, Incorporated (DRI). The supply projections, perhaps the most distinctive feature of this study, were based on a model that incorporates all major sources of response to changes in demand. Developed under contract to NSF by Drs. Robert DauffenBach (Oklahoma State University) and Jack Fiorito (University of Iowa), these projections are intended to identify potential problems within the SET labor market, as well as to assist in understanding the dynamics and flexibility of SET labor supply.

Although both models represent the state-of-the-art in projection methodologies, it is nonetheless important to be aware of certain methodological limitations. First, the projections are only as accurate as the assumptions that were used to generate them. To the extent that these assumptions are not realized, projections are likely outcomes, not precise predictions. For this reason, the analysis uses four sets of assumptions based on alternative macroeconomic conditions and defense-expenditure patterns to generate a range of potential outcomes. Second, this type of analysis provides only a broad overview of the SET labor market, highlighting potential problem areas. Problems of a more disaggregated nature generally cannot be modeled empirically, but lend themselves more readily to qualitative studies. Limitations of the analysis will be highlighted throughout the report to assist in evaluation of the results.

Despite these limitations, the methodology developed provides a most useful framework for assessing potential supply/demand imbalances of SET personnel and is sufficiently versatile to be used in estimating the potential impacts of future policy changes.

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highlights

• Four projection scenarios were developed for the 1982-87 period to generate a likely range of employment estimates. These scenarios represented combinations of low and high macroeconomic activity—average annual growth rates in gross national product (GNP) of 1.6 percent and 4.3 percent, respectively, and low and high growth rates in real defense expenditures—annual growth rates of 3.1 percent and 8.1 percent, respectively. Performance of the economy and defense outlays recorded during the first year and a half of that period suggest that actual employment will lie within the projected range of estimates The scenarios indicate that the number of jobs requiring science, engineering, and technician (SET) skills in the United States can be expected to increase by 460,000 to 740,000 over the 1982-87 period. By the latter year, roughly 4 million jobs are projected to be required in SET occupations, representing about 3.5 percent of total employment.

• Among the 12 science and 9 engineering occupations studied, only the rapid growth in requirements for aeronautical/astronautical engineers, computer specialists (computer systems analysts and programmers), and electrical/electronic engineers is likely to produce shortages of fully qualified professionals; shortages are defined as a 5-percent, or greater, shortfall in supply of new, appropriately trained college graduates and experienced workers. By 1987, the projected shortfall for aeronautical/astronautical engineers will vary from 15 percent to 45 percent, representing 10,000 to 35,000 personnel; for computer specialists, the comparable range is projected to be 15 percent to 30 percent, about 115,000 to 140,000 personnel. At high projected levels of defense expenditures, the shortfall of electrical/electronic engineers may almost reach 10 percent of supply, roughly 30,000 personnel. Growth in the numbers of mechanical and industrial engineering technicians as well as drafters is projected to accelerate over the next 5 years suggesting potential supply problems.

• Occupational mobility can be expected to alleviate shortages as experienced workers switch occupations in response to changing job opportunties. Sustained, high dependence on occupational mobility to meet growing requirements in any particular field, however, indicates a potential problem in maintaining the quality of the work force. This problem is itself a manifestation of labor shortages. By 1987, it is projected that 11 percent to 15 percent of the supply of aeronautical/astronautical engineers will need to be drawn from other occupations to meet increasing employment demands, for computer specialty occupations the comparable range lies close to 11 percent of supply.

• The defense industrial base is highly dependent on SET personnel; roughly 15 percent of the defense work force is employed in SET occupations as opposed to 3 percent of that in nondefense. Because defense spending is concentrated in high-technology manufacturing industries, SET employment projections show a marked sensitivity to variations in defense spending despite the latter's small share of GNP. During the 1982-87 period, projected growth in employment for SET personnel is much stronger in defense- than in nondefense-related activities By 1987, roughly 4 percent of scientists, 15 percent of engineers, and 7 percent of technicians are projected to be employed in defense activities, a slight increase over the 3 percent, 12 percent, and 6 percent, respectively, employed in such activities in 1982. Among SET occupations, defense expenditures have their strongest impact on the engineering work force.

• Growth in requirements for SET personnel is projected to be concentrated in a few industries that are also an important part of the defense industrial base. Five industries are projected to generate about three-quarters of the net increase in requirements for engineers—electrical machinery, fabricated metals, nonelectrical machinery, transportation equipment (including aircraft), and business services.

• Science employment is projected to increase from 730,000 in 1982 to between 845,000 and 890,000 in 1987, at an annual growth rate ranging from 3.0 percent to 4.1 percent. Regardless of scenario, computer systems analysis is projected to be the fastest growing science occupation as computer applications continue to proliferate. The rate of employment growth in this occupation is expected to range from 5.6 percent to 6.7 percent per year. Among noncomputer-related occupations, social science will grow fastest, increasing at a projected annual rate of 2.2 percent to 3.2 percent.

• According to the projections, science employment will continue to be concentrated in nonmanufacturing industries. Within the nonmanufacturing sector, business and miscellaneous service industries are expected to maintain their importance as primary sources of employment demand, together generating one-third of both the level and the growth of science employment during the 1982-87 projection period.

• Requirements for engineers are projected to increase from 1.1 million in 1982 to between 1.3 and 1.4 million in 1987, an annual growth rate of between 2.6 percent and 4.5 percent. Two engineering fields—aeronautical/astronautical and electrical/electronic—are projected to grow faster than average. Employment growth in the former is expected to range from 5.9 percent to 11.1 percent per year; for the latter, an annual growth rate of 3.9 percent to 5.1 percent is expected.

• Requirements for S/E technicians are projected to increase from 1.5 million in 1982 to between 1.6 million and 1.8 million in 1987, indicating an average annual growth in employment ranging from 2.4 percent to 3.7 percent. In response to the diffusion of computer technology, computer programming will be the fastest growing technician occupation, with annual growth in employment ranging from 4.3 percent to 5.0 percent. Strong employment growth is also projected for electrical/electronic and mechanical engineering technicians. Employment of the former is projected to grow in a range of 3.0 percent to 4.0 percent, paralleling strong demand for engineers with that specialty: for the latter, employment growth is projected to range from 2.5 percent to 5.0 percent.

I. introduction

policy issues

The National Science Foundation (NSF) is mandated by Congress to provide information on the availability of the current and projected need for scientific and technical resources in the United States. This function includes monitoring operations of the labor market for scientists, engineers, and technicians. Although these personnel constitute less than 5 percent of the labor force, they are essential to the high-technology industries critical to our national security, general economic growth, and technological innovation. Major initiatives in any of these areas strongly influence the scientific and technical labor market and are highly dependent on the efficiency of this market's functioning for their outcome.

The concern for improving national security that led to the defense buildup undertaken in the early eighties was an example of such an initiative. As depicted by the five-year defense plan (FYDP) proposed by the President for fiscal year 1983 (FY 1983), this buildup represented the largest, planned peacetime increase in defense spending in U. S. history. According to that plan, total obligation authority (TOA) for defense was scheduled to increase by $186 billion in nominal terms between 1982 and 1987, a real increase of nearly 45 percent.[1] There has been some concern over the ability of the science, engineering, and technician (SET) work force to accomodate the additional demands being placed on it. This concern has arisen not only because spending has been targeted on high-technology procurements and research and development (R&D) activities that are science and engineering (S/E)-intensive, but also because the labor market has yet to be affected by defense spending decisions implemented in the early eighties.

That the defense buildup is taking place while there is a growing nondefense demand for S/E personnel further complicates the issue. Even before the increase in defense expenditures, S/E employment in industry had begun to outpace growth in the total work force. The reasons for this were the strong economic performance of high-technology industries and the industrial staffing changes that increased the utilization of S/E personnel relative to the number of workers in other occupations. In addition to industry's need for scientists and engineers to increase productivity and to remain competitive internationally, academia also needs additional S/E personnel (particularly engineering and computer science faculty) to fill existing vacancies and to meet future training needs.[2]

objectives

Because SET job skills are highly specialized and require lengthy training periods, the SET labor force cannot easily adapt to sudden large increases in requirements. The question that arises, therefore, is whether a large, rapid increase in the need for defense-related personnel, coupled with growing industrial and academic requirements, will make unrealistic adjustment demands on the SET labor market. In undertaking an analysis of this problem, two objectives were sought: To project the levels of SET employment that would likely be needed to meet both defense and nondefense requirements during the period covered by the FY 1983 FYDP; and, to project supply response to increasing requirements, identifying the potential shortfalls that may arise. The shortfalls, in turn, will serve to highlight general areas of concern.[3]

Labor markets accomodate demand and supply imbalances; thus, it is unlikely that shortages would be fully manifested in unfilled job vacancies. Employers make a variety of adjustments when faced with shortfalls in labor supply. Some postpone, or even cancel, projects or entire programs.

[1] Data Resources, Inc., "The 1984 Defense Budget Economics and Politics," *Defense Economics Research Report*, Vol III, No 1, January 1983.

[2] G. A. Keyworth, Statement before the Committee on Science and Technology, *U.S. Science and Technology Under Budget Stress*, Hearings Before the Committee on Science and Technology, U.S. House of Representatives, 97th Congress (Washington, DC: Supt of Documents, U.S. Government Printing Office, 1982).

[3] This methodology can at best only hint at the more specialized problems of this labor market that are of policy concern. Such problems include (1) labor market imbalances in subspecialties or emerging fields, (2) the need for experienced, as opposed to newly trained, S/E personnel; (3) the need for young investigators in basic research; or, (4) labor market imbalances arising from geographic segmentation.

Alternatively, as observed during the rapid defense and space buildup of the fifties and sixties, employers may adapt by downgrading the quality of their work forces—placing greater reliance on new college graduates in the absence of experienced personnel, upgrading technicians, or retraining workers from other occupations. Employers may also compete for necessary personnel by bidding up wages. This can affect whole sectors of the economy, with Government, industry, and academia competing with one another for available workers. Those industries and sectors that cannot effectively compete for essential personnel may suffer as a consequence.

All of these adjustments exact very real costs, and a relevant policy question is whether traditional free market mechanisms will make appropriate personnel allocations with minimal dislocation of the economy. For purposes of this analysis, therefore, a shortage cannot be defined simply as "unfilled job vacancies," but rather as "an inadequate supply of appropriately trained and experienced personnel."

methodology

Two state-of-the-art simulation models were used in this analysis. Employment demand through 1987 was projected for 29 SET occupations using the Defense Interindustry Forecasting System (DIFS) developed by Data Resources, Incorporated (DRI). (See technical notes, Defense Interindustry Forecasting System. Employment Projections.) Because projections are highly dependent on the assumptions underlying them, four scenarios were run to determine the likely range of total requirements, including the relative importance of defense expenditures in determining SET employment demand. These four scenarios were based on assumptions governing both the level of macroeconomic activity and the alternative patterns of defense-expenditure growth.

Projected labor market balance is determined by comparing estimates of labor demand and supply. The projections of S/E supply for this study were derived from an NSF-sponsored model developed by Drs. Robert DauffenBach, Jack Fiorito, and Hugh Folk. (See technical notes, "DauffenBach/Fiorito/Folk (DFF) Model Stock Flow Model of Science and Engineering Labor Supply.") The DFF model, as it will be referred to throughout this report, provides annual projections of supply in 21 occupations by modifying the previous year's stock of personnel with flows of new labor force entrants, occupationally mobile experienced workers, and immigrants.[4] Each of these flows was modeled to respond to changes in employment across occupations, recognizing that variations in job opportunities elicit changes in available supply. In total, four sets of supply projections were generated—one based on each requirement scenario developed with the DIF System.

methodological caveats

It is important to realize that projections are not predictions, and that there are methodological limitations inherent in simulation modeling that must be considered in evaluating the likelihood that projections will be realized.

First, the quality of projections depends on the assumptions made about the exogenous variables that drive simulation models. In this analysis, for example, variables defining macroeconomic performance and defense expenditures were critical to estimating future SET employment with the DIFS model. Because neither the behavior of the economy nor future defense outlays can be predicted with certainty, this analysis used alternative scenarios that made allowances for variations in performance in these areas.

Second, projections from simulation models are based on relationships among major economic variables. These relationships are determined by empirical analyses of historical data and define the structure of the economy. If some occurrence (major monetary or fiscal policy changes, dramatic labor market disruptions, prolonged periods of high inflation, etc.) alters that structure, models may no longer reflect operations of the economy. Technological change is an example of structural change that could significantly affect the projection of future demand for SET personnel. Such change is incorporated in the DIF System both in determining industrial production and in defining staffing patterns within industry. There is some concern, however, that automation in the work place (robotics, computer-aided design and manufacture (CAD/CAM), etc.) will accelerate SET employment growth at rates far in excess of those anticipated by studies generating employment projections. Although the pace of automation has quickened, there is little reason to expect dramatic changes in requirements for SET personnel over the short 5-year period being simulated.

organization of remaining sections

The main body of this report is divided into two sections. The first provides an overview of the DIF System that was used to generate employment projections of SET personnel. It presents pertinent assumptions underlying the four scenarios chosen for analysis, and reports total and defense-related employment requirements through 1987. The second section describes the DFF labor supply model, presents information on the importance of various components of S/E labor supply, and provides comparisons of demand and supply projections to assess potential labor market balance. An assessment of projected labor market balance for S/E support technicians is also presented in this section.

[4]The DFF model does not produce supply estimates of S/E support technicians because informal training mechanisms make it much more difficult to identify the potential supply for these occupations. Historic and projected growth rates in employment will be compared in order to identify potential difficulties in meeting anticipated growth requirements.

II. employment projections

projection scenarios

Projections are forecasts that are conditional on a variety of assumptions that depict economic, institutional, and social conditions. This analysis was therefore designed not to provide a single numeric estimate of future employment requirements, but instead to provide a well-defined range within which employment growth is likely to occur during the 1982-87 period. Two factors were assumed to be major determinants of SET employment, based on their ability to affect the level and pattern of industrial activity: (1) General performance of the U.S. economy, and (2) the level and distribution of defense expenditures.

In total, four projection scenarios were developed using the DIFS model developed by DRI. These scenarios were based on two alternative sets of macroeconomic assumptions designed to encompass likely private sector performance during the simulation period.[5] Each of these, in turn, was combined with two alternative sets of assumptions about defense spending. The scenarios were run in September 1982, with the first projection period starting in the third quarter of that year.

[5] DRI specializes in economic forecasting. The projection scenarios used in this analysis were developed in collaboration with DRI staff

macroeconomic assumptions

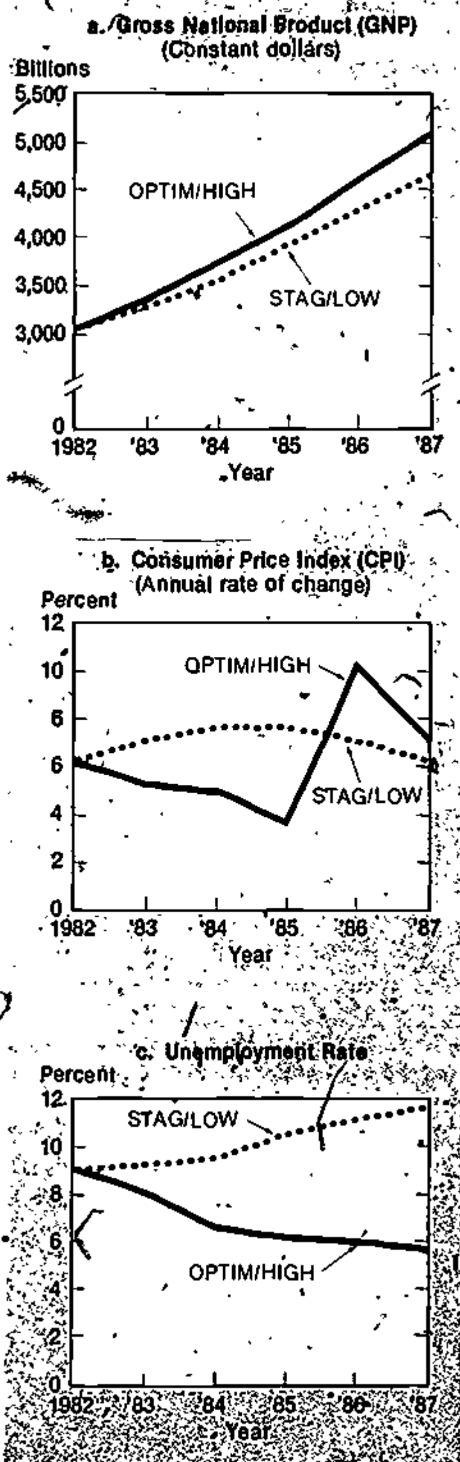
Low-growth scenarios. Of the two sets of assumptions underlying the projections, forecasting the performance of the U.S economy was more problematic. The U.S. economy has been unpredictable since the late seventies when concurrent high rates of unemployment and inflation characterized what came to be called a "stagflated" economy. This type of economy formed the basis of the low-growth (STAG) scenarios used in the analysis. These scenarios assumed that a weakened economy would characterize the first half of the projection period, but that the second half would see a return to long-run growth. Within the STAG simulations, the inflation rate, as measured by the consumer price index (CPI), was sustained at relatively high levels and averaged over 7 percent per year for the 1982-87 period. During that time, the unemployment rate averaged 10 percent annually, growing steadily from the 9-percent level evident in 1982 (chart 1). During the same period, labor productivity, as measured by output per hour, grew less than 1 percent annually (chart 1 and appendix tables B-1 to B-4).

The economy in the low-growth scenarios was characterized by a steady but relatively slow expansion. After registering a decline in 1982, real GNP grew at positive rates throughout the remainder of the simulation period, averaging somewhat less than 2 percent. Employment in SET occupations is highly dependent on industrial performance, especially within manufacturing industries. Among the major depressants of SET employment within these scenarios was the sluggish manner in which the manufacturing sector made up for production losses that occurred in 1982. Over the simulation period, capacity utilization in manufacturing industries rarely exceeded 75 percent.

High-growth scenarios. The high economic growth (OPTIM) scenarios provided the upper range of SET employment estimates for this study. The first three years of the simulation period were characterized by relatively vigorous economic growth, after which time the simulation was eased toward long-run growth. Over this period, it was assumed that the inflationary expectations developed during the seventies could be broken, and thus the average annual growth in the CPI was restricted to 5 percent. In contrast to the previous scenarios, unemployment declined steadily, falling to almost 6 percent in later years. Growth in labor productivity during the two years following 1982 rebounded to levels not recorded since the mid-seventies, then moderated to average 2 percent over the entire projection period.

In the OPTIM scenarios, real GNP growth exceeds 4 percent per year, rebounding from the decline registered in 1982. By the end of 1983, these scenarios depict a growth in industrial production that more than compensates for 1982 losses. On average, manufacturing industries show the largest production gains, resulting in projected

Chart 1. Range of macroeconomic assumptions used to generate employment projections: 1982-87



NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.
SOURCE: National Science Foundation

rates of capacity utilization exceeding 80 percent by 1987.

defense-expenditure assumptions

High-defense expenditure scenarios. The high-defense expenditure (HIGH) scenarios used for this analysis assumed that the FY 1983 FYDP would be implemented without change. According to this FYDP, TOA—the total appropriation needed to execute the proposed buildup—is scheduled to increase by $186 billion in nominal terms between 1982 and 1987, a real increase of almost 45 percent (table 1). Most of the spending is aimed at force modernization, concentrating primarily in the procurement of new and technologically sophisticated weapons systems, as well as in research, development, and testing evaluation (RDT&E) budget accounts.[6] By 1983, TOA in these two accounts was anticipated to increase by 36 percent and 21 percent, respectively, dramatically shifting the composition of the defense budget toward expenditures that most directly affect SET employment.

Because the actual disbursement of funds affects industrial production and employment, the DIFS model translates TOA into actual defense outlays as contracts and expenditures are made. Between 1982 and 1987, defense expenditures in the HIGH scenarios were anticipated to grow at an 8-percent average annual rate in real terms. The annual growth in defense expenditures is highest during the 1983-85 period, reflecting the impact of procurement programs initiated one to two years earlier (chart 2).[7]

Low-defense expenditure scenarios. Low-defense expenditure (LOW) scenarios constrain real growth in defense spending to nearly 3 percent during the same period.

[6] As an example the FY 1982 and FY 1983 budgets include large increases in major weapon systems purchases by the three branches of the military. Over 1 300 new aircraft were being requested, as well as two Trident submarines, two nuclear powered carriers, nearly 140 new ships, and the sophisticated M-1 Abrams Tank.

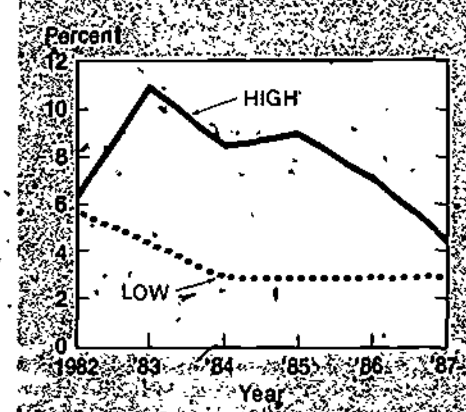
[7] It takes several years for TOA in procurements to affect the economy. Based on analysis of past spending patterns only 12 percent of TOA shows up as first-year outlays. The majority of actual expenditures, two thirds, generally occurs two to three years after appropriation.

Table 1. Summary statistics on the fiscal year 1983 Five-Year Defense Plan: 1982-87

Defense budget	1982	1987
Total obligation authority:		
Current 1983 dollars (billions)	$214 3	$400 8
Constant 1983 dollars (billions)	227.6	325 9
Defense outlay expenditures:		
Current 1983 dollars (billions)	182.8	356.0
Constant 1983 dollars (billions)	195.4	288.7
Components of defense budget (percent):		
Operations and maintenance	34.0%	26.1%
Procurement	23.2	39.4
Military personnel	21 5	14 0
Research, development, and testing	10.3	10 7
Retirement	8 4	5 9
Military construction	2 7	3 9

SOURCE: Data Resources, Incorporated

Chart 2. Range of defense-expenditure assumptions used to generate employment projections: 1982-87 (Annual rate of change, constant dollars)



SOURCE: National Science Foundation

Such growth would be nearly 2 percentage points below the recommendations set by the Carter Administration in 1980 and were deemed sufficiently conservative to provide a lower bound for this analysis. Under the LOW scenarios, personnel and retirement accounts were left at levels proposed by the current Administration, reflecting the infeasibility of adjusting these budget accounts downward. The entire difference in defense-expenditure growth between the LOW and HIGH scenarios was, therefore, confined to reductions in procurement, operations and maintenance (O&M), and RDT&E budget categories.

assessing underlying assumptions

Since this analysis was begun, several quarters of economic performance and issuance of the FY 1984 FYDP have provided an opportunity to assess assumptions underlying the four scenarios. In the first half of 1983, the U.S. economy has shown a vigorous recovery. Real GNP has grown 5 percent per year, inflation has held ground at a 3-percent annual increase, the unemployment rate has fallen to 7 8 percent, and both productivity and industrial production are up.[8] Although an assessment of long-run economic performance cannot be founded on short-run statistics, a continuation of the recovery, even if it were to moderate, might show the OPTIM scenario assumptions to be slightly conservative. With regard to the defense buildup, signals are mixed. The FY 1984 FYDP has reinforced the Administration's commitment to maintaining the course it set earlier. During 1983, however, contract awards were delayed and Congress, in the face of large Federal deficits, has approved only a 5-percent real increase in defense outlays cutting procurement, O&M, and RDT&E accounts. Therefore, it appears that defense outlays will fall somewhere midrange of the two alternatives simulated. Indications are that deviations in the two sets of assumptions may be offsetting, with likely employment levels still falling within the original projected range.

projected range of SET requirements

The STAG/LOW and OPTIM/HIGH scenarios define the maximum range of employment and will form the basis for the analysis presented. According to these scenarios, the number of jobs for appropriately trained and experienced workers in SET occupations will increase by 460,000 to 740,000 between 1982 and 1987. By the end of that period, it is estimated that nearly 4 million people will be required in these occupations, representing about 3.5 percent of total employment.[9]

Growth in SET requirements is expected to increase by 2 6 percent to 4 1 percent annually through 1987, significantly in excess of the 1 0- to 2 4-percent annual growth rate in overall employment. This is very much in keeping with the recent trend characterizing the U S economy, namely, the growing technical sophistication of the labor force. Two NSF studies have shown that SET employment growth has been outpacing that of total employment in recent years, both in the manufacturing and nonmanufacturing industrial sectors.[10] This has occurred in part because of the strong performance of high-technology industries that are characterized by work forces with high concentrations of SET personnel. But more importantly, it has occurred because the diffusion of technology throughout the economy has resulted in changes in the staffing requirements of industries. Both NSF studies have found that changes in staffing pattern are the driving force behind SET employment growth, accounting for roughly four-fifths of the increase in science employment and over one-half of that for engineers and technicians Changes in the pattern and level of industrial growth, as well as those in staffing, are reflected in the DIFS model, and were factors in determining the requirement projections

The wider the range of employment requirements generated in an analysis, the more difficult it is to draw meaningful conclusions. The four scenarios developed for this study, however, resulted in a well-defined range of projected SET requirements; never varying by more than 5 percent from the average 1987 projected value in any of the major occupational categories (chart 3). The reasons for this are twofold. First, only a small fraction of jobs in the economy require highly specialized SET skills. Very large swings in industrial production would be needed to generate overall changes in employment that would result in a wider range of projected SET requirements. Such swings are not realistic given recent economic performance and the short-time horizon being simulated. Second, it is also important to make note of the different growth rates for productivity that characterize the scenarios. Productivity, defined as output per worker, increases twice as fast in the OPTIM as it does in the STAG scenarios. These productivity gains counterbalance the employment impact of the more rapid industrial expansion found in the former, ultimately reducing the need for additional workers.

the effect of defense expenditures on SET employment

Changes in national priorities often have a high-technology emphasis and, hence, a significant impact on the level and/or pattern of SET skill requirements. The

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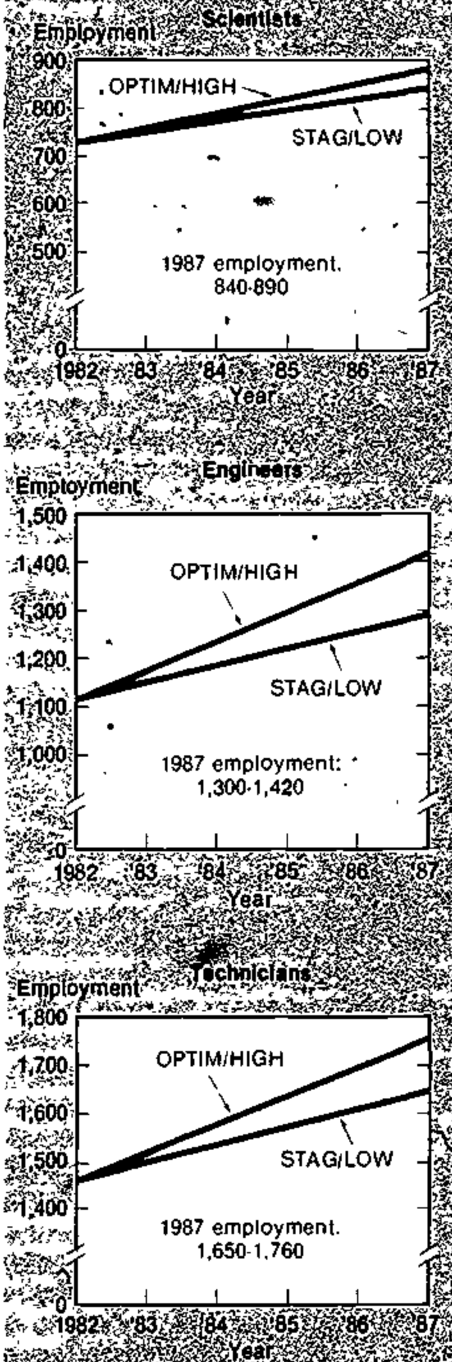
[8] The Rebound is Breaking Records But the Stronger it is Now the Tougher it will be to Moderate. *Business Week*, August 11, 1983, pp 28-30

[9] There is no single accepted set of criteria used to define this population The demand projections in this report are estimates of the number of jobs requiring SET skills These projections are primarily based on data from the Bureau of Labor Statistics Occupation Employment Statistics (OES) Survey This establishment survey classifies individuals as scientists and engineers if their job requires a functional level comparable to that of a 4-year university graduate in an S/E-related field The functional level of technicians is assumed to be comparable to that achieved through related postsecondary school training S/E employment estimates derived from this survey are lower than those generated in NSF surveys because many S/E personnel who are managers, administrators, or professors are not associated with an S/E field.

[10] National Science Foundation, *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries* 1977-80 (Final Report) (NSF 82-331) (Washington, D C, October 1982) and Technical Employment Growth Accelerates in Selected Nonmanufacturing Industries, *Science Resources Studies Highlights* (NSF 83-321) (Washington, D C, October 17, 1983).

Chart 3. Projected range of employment in science, engineering, and technician occupations: 1982-87¹

(In thousands)



¹Employment ranges are derived using average annual growth rates in each of the scenarios given. Actual employment estimates are anticipated to fall within this range only if all assumptions are met.

NOTE: STAG/LOW indicates low-economic growth / low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth / high-defense expenditure scenario.

SOURCE: National Science Foundation.

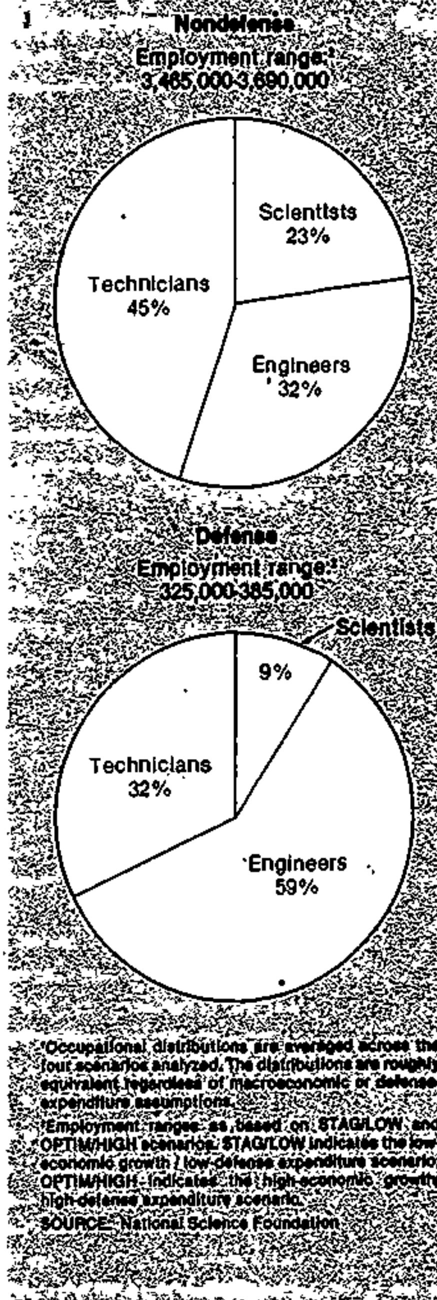
primary reason for undertaking this special study was to assess the degree to which the SET labor market could adjust to meet the additional demands generated by the defense buildup that resulted from the renewed emphasis of national security begun in the early eighties. As originally planned, this buildup called for a 45-percent increase in real defense spending over a relatively short 5-year period and may place significant demands on the SET labor market.

The anticipated effect of defense spending on the SET labor market is generated by the former's targeting on the high-technology sector that directly or indirectly supports the production of sophisticated weapons systems.

A number of recent studies have presented estimates of the impact of defense spending on industries and occupations. Models such as DIFS, that have been used to estimate defense-induced employment, corroborate the assumptions that defense requirements represent a significant fraction of overall employment in high-technology industries. For example, defense contracts support nearly one-half of the employment used to manufacture aircraft and ships, one-fifth of employment to produce electrical machinery and equipment, and one-sixth of the employment needed to make scientific and control equipment. Moreover, within these industries, growth rates of defense-related employment are highly sensitive to defense spending levels.

Durable-goods manufacturing industries, such as those just mentioned, staff large numbers of scientists, engineers, and technicians within their work forces. The targeting of defense expenditures on these industries is the major reason why nearly 10 percent of the SET labor market is employed in defense-related activities. The importance of SET personnel to the defense industrial base is reflected in the share of its work forces employing these skills—SET personnel comprise over 15 percent of defense work forces, a share significantly higher than the 3 percent found in nondefense employment. The occupational composition of SET work forces engaged in defense- and nondefense-related activities also differs in response to variations in concentration within manufacturing industries, with defense employment much more geared to engineering professions (chart 4).

Chart 4. Projected occupational distributions of scientists, engineers, and technicians in defense and nondefense sectors: 1987¹



¹Occupational distributions are averaged across the four scenarios analyzed. The distributions are roughly equivalent regardless of macroeconomic or defense-expenditure assumptions.

²Employment ranges are based on STAG/LOW and OPTIM/HIGH scenarios. STAG/LOW indicates the low-economic growth / low-defense expenditure scenario; OPTIM/HIGH indicates the high-economic growth / high-defense expenditure scenario.

SOURCE: National Science Foundation.

In 1982, about 3 percent of scientists, 12 percent of engineers, and 6 percent of technicians were employed in defense-related activities. On average across the four scenarios, these proportions are projected to rise somewhat to 4 percent, 15 percent, and 7 percent, respectively, by 1987 (chart 5 and appendix tables B-5 to B-8) Requirements in several occupations, however, appear to be relatively more sensitive to defense-related activities than macroeconomic performance and can be expected to be essential in implementing proposed defense programs. About one-half of all aeronautical/astronautical engineers were employed in defense-related activities in 1982, and by 1987 the proportion is projected to rise to almost 60 percent. The share of electrical/electronic engineers in defense employment is projected to rise from 13 percent to 15 percent by 1987, mechanical engineers from 9 percent to 12 percent, and mechanical engineering technicians from 18 percent to 22 percent.

Although the defense share of employment is relatively small in most SET occupations, those occupations with the largest share of defense requirements tend to be the ones that either demand highly specialized skills or are fields that currently or recently have undergone shortfalls in supply. In each of these fields, as is the case across all SET occupational categories, projected growth in defense employment far exceeds that in nondefense employment (table 2). Thus, defense expenditures not only contribute significantly to the current levels of SET employment, but can also be expected to contribute disproportionately to its growth over the projection period.

total projected requirements for scientists, engineers, and technicians, 1982-87

The foregoing discussion highlights the anticipated importance of defense spending during the 1982-87 period: Although defense-related activities are expected to represent a significant proportion of total SET requirements, the majority of such requirements, nonetheless, will continue to be in nondefense activities Therefore,

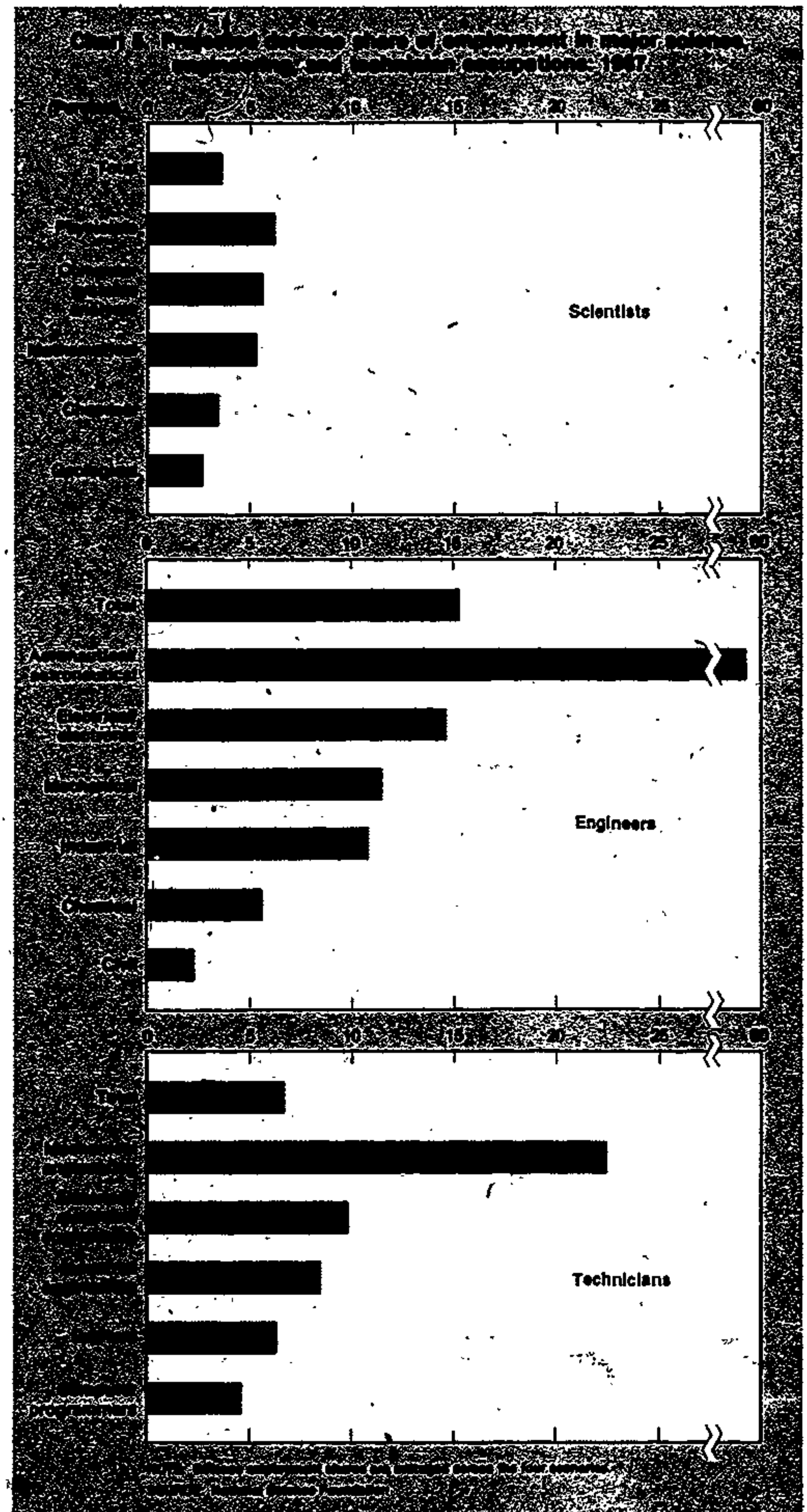


Table 2. Projected growth rates of defense and nondefense employment in major SET occupations: 1982-87

(Percent)

Occupation	STAG/LOW		OPTIM/HIGH	
	Defense employment	Nondefense employment	Defense employment	Nondefense employment
Total scientists	6.1	2.9	9.2	3.9
Chemists	4.0	1.4	5.5	2.4
Computer systems analysts	8.9	5.4	12.3	6.4
Life and physical, n.e.c.	5.1	1.3	9.5	2.4
Mathematical	3.1	2.1	7.8	3.3
Physicists	3.4	1.2	7.9	2.6
Total engineers	6.1	2.1	10.2	3.6
Aeronautical/astronautical	8.5	2.7	14.1	7.3
Electrical/electronic	6.4	3.5	9.0	4.5
Industrial	5.0	1.6	9.0	3.0
Mechanical	5.4	1.7	9.5	3.5
Total technicians	5.0	2.2	8.0	3.4
Computer programmers	6.1	4.2	8.4	4.8
Electrical/electronic engineering	5.7	2.7	8.4	3.6
Industrial engineering	4.0	1.6	8.1	3.3
Mechanical engineering	5.2	1.8	10.1	3.7

NOTE STAG/LOW indicates low-economic growth/low-defense expenditure scenario, OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario

SOURCE National Science Foundation

any assessment of the adequacy of personnel to meet defense requirements must be undertaken in the context of the total needs of the economy.

scientists

Over the period being analyzed, slightly more than one-fifth of the SET work force will be employed in jobs that require a skill level equivalent to that obtained through a university degree in a science-related field.[11] Employment requirements in these occupations are projected to increase within a range of 3.0 percent to 4.1 percent per year between 1982 and 1987, indicating a moderation of the 8.7-percent average annual growth rate that occurred between 1977 and 1982 (table 3).[12] By 1987, employment in these occupations is anticipated to reach 845,000 to 890,000, implying a net addition of 120,000 to 160,000 jobs over the 5-year period being analyzed.

In comparing the four macroeconomic/defense-expenditure scenarios, projected requirements in science occupations demonstrated little sensitivity to the differences between defense-expenditure alternatives used, but substantial sensitivity to variations in the general performance of the U S. economy. The reason is that the majority of science jobs are concentrated in nonmanufacturing industries which are not themselves major recipients of defense contracts and awards. Among these industries, the projections show that business and miscellaneous service industries can be expected to continue as the primary sources of employment demand for these fields, together they generate one-third of

Table 3. Projected employment in science occupations: 1982-87

(In thousands)

Occupation	1982 employment	Projected employment			
		STAG/LOW		OPTIM/HIGH	
		1987 employment	Annual growth rate (percent)	1987 employment	Annual growth rate (percent)
Total scientists	727	843	3.0	888	4.1
Agricultural	17	17	.1	18	1.4
Biologists	55	59	1.4	62	2.4
Chemists	91	98	1.5	103	2.5
Computer systems analysts	219	287	5.6	303	6.7
Geologists	43	48	2.3	48	2.3
Life and physical, n.e.c.	28	30	1.3	31	2.5
Mathematical	51	57	2.2	61	3.5
Physicists	21	22	1.4	24	3.0
Social	202	225	2.2	237	3.2
Economists	30	35	2.8	36	3.6
Psychologists	90	100	2.1	106	3.2
Sociologists	9	10	1.7	11	2.8
Social, n.e.c.	72	79	1.9	84	3.0

NOTES. Because of rounding, components may not correspond to totals STAG/LOW indicates low-economic growth/low-defense expenditure scenario, OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation

[11] The Occupational Employment Survey (OES) assigns occupation by primary work activity This results in an underestimation of S/E employment in academia since individuals whose major responsibility is teaching are categorized in a general occupation of Professor, and not in their S/E discipline Because of the relative importance of academia as a source of employment, the undercount should be more significant for scientists than engineers and would vary across disciplines Using NSF data on type of employer and the proportion of faculty spending less than one-half their time in R&D activities rough estimates of undercounts in various fields can be determined For physical scientists the undercount of requirements may be as high as 12 percent, mathematical scientists 29 percent life scientists 24 percent social scientists 24 percent and engineers 1 percent National Science Foundation *U S Scientists and Engineers 1980* (Detailed Statistical Tables) (NSF 82-314) (Washington D C 1982) and Westat Inc *Research Participation and Other Characteristics of Recent Science and Engineering Faculty* Vol I Contract No SRS-7920876 (Rockville Md May 1981)

[12] The 1977-82 growth rates for SET employment reported throughout the text are based on data from the Bureau of Labor Statistics Current Population Survey (CPS)

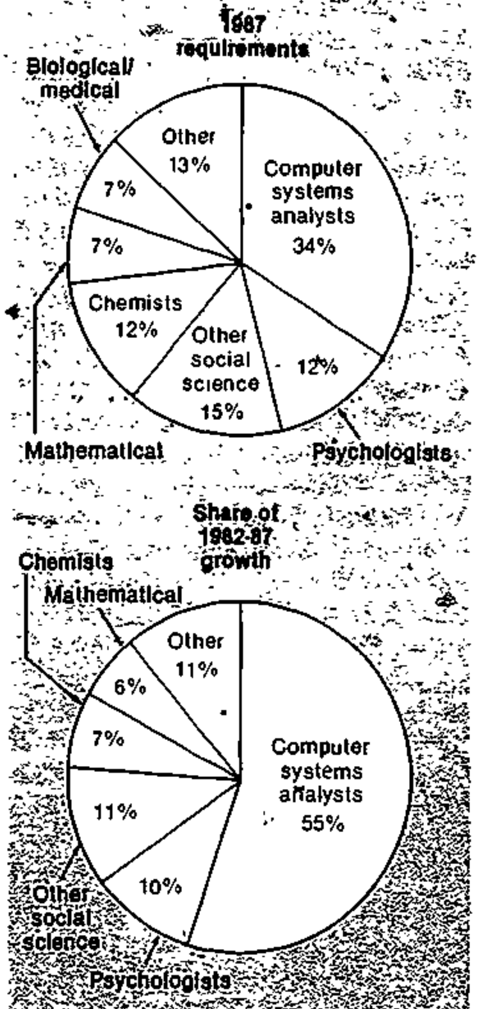
both the level and growth of science employment over the projection period (table 4). The business service industry is comprised of a variety of establishments whose work forces contain large concentrations of SET personnel: R&D laboratories; management consulting and commercial testing firms, and computer and data processing establishments. The majority of science employment in the miscellaneous service industry is also concentrated in establishments with technically sophisticated work forces: scientific, engineering, and surveying service establishments, as well as nonprofit educational, scientific, and research organizations.

By 1987, the majority of science employment is projected to be concentrated in three occupations: computer systems analysts, psychologists, and chemists (chart 6). The importance of the computer systems analyst occupation in determining projected requirements is also reflected in its contribution to the growth of science occupations over the analysis period, accounting for over half the total increase in requirements.

Computer systems analysts. The dominant force behind employment growth in science occupations over the past decade has been the rapid diffusion of computer technology both in business and in S/E applications. Although it was not until the 1970 decennial census that this job category became sufficiently large to become a part of data collection efforts, by 1987 the projection scenarios estimate that 290,000 to 305,000 people will be required to perform this job function. Roughly half these personnel are expected to be employed in business services (25 percent), finance, insurance, and real estate (12 percent), and the wholesale and retail trade industries (12 percent).

Growth in this occupation will not be confined to industries that are major employers, however. Decreasing costs, reductions in size, and expanding applications have made the computer adaptable to a wide variety of employment environments with the result that most industries are expected to staff higher concentrations of people with these skills. As a result, between 1982 and 1987, projected employment for computer systems analysts is expected to increase by 5.6 percent to 6.7 percent per year, a rate almost three times as rapid as those in other major fields of science. Such growth will create an additional 70,000 to 85,000 job opportunities over that 5-year period.

Chart 6. Distribution of projected 1987 requirements and 1982-87 growth in science occupations



NOTE: Based on average distributions across scenarios. For requirements, the results are equivalent across macroeconomic/defense expenditure scenarios; at lower levels of macroeconomic performance and defense spending, however, computer systems analysts represent a larger share of growth.

SOURCE: National Science Foundation

Expanding job opportunities in this occupation will draw on S/E personnel from other fields, to some extent masking the need for personnel with other training. In a science environment, most employers require systems analysts to have a strong foundation in physical sciences, mathematics, or engineering; in business environments, knowledge of economics,

Table 4. Major industries determining projected level and growth in science employment: 1982-87

Industry	1982 employment level (thousands)	STAG/LOW Employment 1987 Level (thousands)	STAG/LOW Employment 1987 Distribution (percent)	STAG/LOW Growth 1982-87 Annual growth rate (percent)	STAG/LOW Growth 1982-87 Share of growth (percent)	OPTIM/HIGH Employment 1987 Level (thousands)	OPTIM/HIGH Employment 1987 Distribution (percent)	OPTIM/HIGH Growth 1982-87 Annual growth rate (percent)	OPTIM/HIGH Growth 1982-87 Share of growth (percent)
Total major industries	402	470	56	3.2	61	491	.55	4.1	55
Business services	119	148	18	4.4	25	157	18	5.5	23
Chemicals	52	57	7	1.9	5	58	6	2.5	4
Finance, insurance, and real estate	52	65	8	4.4	11	65	7	4.6	8
Mining	29	32	4	2.3	3	32	4	1.7	2
Miscellaneous services	118	130	15	1.9	11	138	16	3.0	12
Wholesale and retail trade	32	38	4	3.7	6	41	5	5.2	6
All other industries	324	373	44	2.8	39	397	45	4.1	45

NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation

accounting, or business management is often considered important.[13] Over the years, it has become increasingly difficult to draw the line between computer science itself and use of the computer as a tool in various other disciplines. It is because of the flexibility of the S/E work force in meeting the need for computer-related skills, however, that this occupation has been able to grow so rapidly.

Social scientists. Requirements in social science occupations are projected to provide between 225,000 and 235,000 jobs in 1987. These estimates may, in fact, understate employment needs in this occupational category since significant numbers of social scientists are employed in academia. To the extent these individuals state teaching as a primary work activity, they will not be associated with their basic area of study by the data base used to predict occupational staffing assignments. Outside of academic employment, however, over half of all social scientists work in the nonmanufacturing industries, primarily in miscellaneous services (33 percent), business services (11 percent), and finance, insurance, and real estate (7 percent).

Projected growth in social science requirements is among the fastest of the noncomputer-related science fields, with the average annual growth rate ranging from 2.2 percent to 3.4 percent. This growth is distributed relatively evenly across industries indicating that industrial expansion—not changes in the patterns of staffing within work forces—is generating most of the projected increase in requirements for these workers. In total, between 1982 and 1987 an additional 25,000 to 35,000 jobs are anticipated to be created because of growth in requirements.

Two occupational subcategories dominate social science employment, psychologists (45 percent), and economists (15 percent). Employment requirements for both these occupations are expected to increase at an annual rate of over 3 percent during the projection period. This suggests a continuation of the growing tendency of government and industry to use individuals with these skills as consultants. Psychologists can be expected to benefit from sustained emphasis of human resources development, health maintenance, and program evaluation in such fields as consumer protection, health, education, etc. They can also expect to be increasingly called on to analyze the psychological impact of technological change.[14] Economists, on the other hand, can anticipate an expanding role within industry by applying their theories and statistical techniques in areas essential to business management decisions: marketing, pricing, international finance, and forecasting.

Physical scientists. Because of its increasing utilization in industry and relatively strong ties to increases in defense expenditures, physics is the fastest growing of the physical science occupations with a projected average annual growth in requirements of 1.4 percent to 3.0 percent. The majority of this growth will be concentrated in three fast-growing durable-goods manufacturing industries—fabricated metals, machinery, and transportation equipment. The number of chemists, whose employment is closely linked to the chemical manufacturing industry, is expected to increase at a rate of 1.5 percent to 2.5 percent per year. Growth in requirements for geologists is projected to lie within the same range, primarily resulting from increased needs of the mining and business service industries. In total, the new growth in these three physical science occupations is expected to result in 15,000 to 20,000 additional jobs between 1982 and 1987.

Mathematical scientists. Mathematical science is also projected to be among the fastest growing of the noncomputer science fields. From 1982 to 1987, requirements in this occupation are expected to increase from 2.2 percent to 3.5 percent per year, resulting in 5,000 to 10,000 job opportunities. Similar to physicists, this occupation is sensitive to defense-expenditure assumptions because of its presence in durable-goods industries that tend to receive large awards from military procurement and RDT&E accounts.

Life scientists. The agricultural and biological science occupations show the smallest projected increase in science requirements. Of these two occupations, agricultural scientists are projected to grow the slowest, barely keeping pace with average growth in overall employment. Biological scientists are expected to grow at twice that rate, nonetheless, this growth will fall below that indicated for other science fields. In 1987, combined requirements in these occupations is expected to range from 75,000 to 80,000, yielding 5,000 to 10,000 additional job opportunities.

engineers

Despite the slowdown in economic growth that began in 1979, severe shortages in many engineering fields persisted as late as 1981, primarily because of the rapid growth in S/E employment within private industry. While the supply/demand situation had moved to balance by mid-1983, the rapid growth of the GNP in that year, the anticipated acceleration of technological change, and the large increases in defense spending have generated concern about the adequacy of the future supply of engineering personnel to meet the expected growth in requirements.[15]

According to the projections developed for this analysis, requirements in these occupations are projected to grow between 2.6 percent and 4.5 percent per year between 1982 and 1987 (table 5). Assuming that the recovery will continue and defense spending will remain high, the actual growth rate achieved should be toward the top of that range. There would appear to be, therefore, little indication that growth in demand would fall off appreciably from the 4.7-percent annual growth in employment that was recorded over the 1977-82 period. By 1987, requirements in these occupations are expected to range from 1,295,000 to 1,425,000, implying a net addition of 155,000 to 285,000 jobs.

The concentration of engineers in expanding, high-technology industries is the key factor underlying the anticipated strong growth of requirements in these occupations. The nonmanufacturing business service industry, which has a SET-intensive

[13] Department of Labor, Bureau of Labor Statistics, *Occupational Outlook Handbook: 1982-83 Edition*, Bulletin 2200, April 1982 and *Occupational Projections and Training Data: 1982 Edition*, Bulletin 2202 (Washington, D.C., Supt. of Documents, U.S. Government Printing Office, December 1982)

[14] Department of Labor, *Occupational Outlook Handbook, ibid.*

[15] National Science Foundation, "Industry Reports Shortages of Scientists and Engineers Down Substantially From 1982 to 1983," *Science Resources Studies Highlights* (Washington, D.C., February 17, 1984.) That actual reductions in SET employment did not appear earlier than 1982 could have been, in part, the result of personnel policies. Anecdotal evidence suggests that, in anticipation of future needs, employers are adverse to releasing skilled workers during a recession. Such employment practices would sustain SET employment during economic slowdowns, providing an artificial floor for requirements.

Table 5. Projected employment in engineering occupations: 1982-87

[In thousands]

Occupation	1982 employment	Projected employment: STAG/LOW: 1987 employment	STAG/LOW: Annual growth rate (percent)	OPTIM/HIGH: 1987 employment	OPTIM/HIGH: Annual growth rate (percent)
Total engineers	1,139	1,296	2.6	1,423	4.5
Aeronautical/astronautical	64	86	5.9	109	11.1
Chemical	53	57	1.6	61	2.7
Civil	163	175	1.3	189	2.9
Electrical/electronic	327	396	3.9	421	5.1
Industrial	109	120	2.0	131	3.6
Mechanical	202	224	2.1	248	4.1
Metallurgical	15	16	1.9	18	4.4
Mining/petroleum	28	32	2.8	32	2.7
Engineers, n.e.c.	177	190	1.4	214	3.8

NOTES: Because of rounding, components may not correspond to totals. STAG/LOW indicates low-economic growth/low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation.

work force is projected to be the largest industrial employer of engineers by 1987, representing one-sixth of total requirements and an equivalent share of growth over the 1982-87 period (table 6). Most of the remaining engineers are expected to be employed within durable-goods manufacturing industries, including electrical and nonelectrical machinery, fabricated metals, transportation equipment, etc. Some of the anticipated increase for engineers within these industries will be derived from general employment expansion as production is increased to meet both defense and private sector needs. A significant share of new job opportunities, however, is expected to result from changes in staffing requirements resulting from such factors as technological change and greater emphasis on productivity, quality control, and cost efficiency. These factors will lead to relatively more jobs for engineers within industrial work forces.[16]

In 1987, approximately half of all engineering requirements will be in either electrical/electronic or mechanical subspecialties (chart 7). Combined, these two occupations are projected to account for

[16] National Science Foundation, *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries 1977-80*, op. cit.

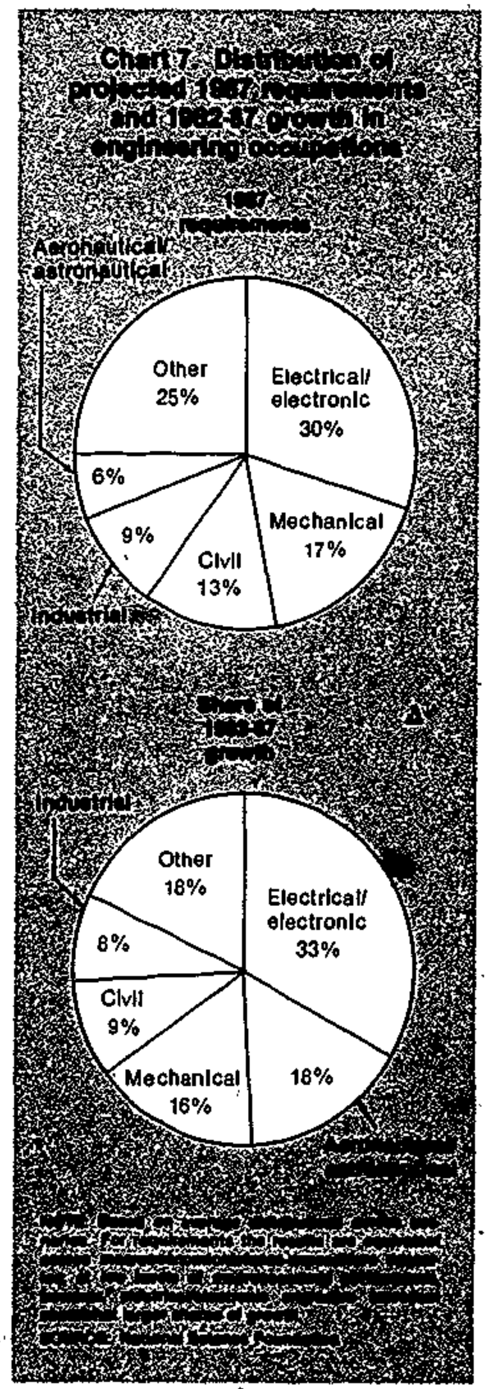


Table 6. Major industries determining projected level and growth in engineering employment

Industry	1982 employment level (thousands)	STAG/LOW Employment 1987: Level (thousands)	STAG/LOW Employment 1987: Distribution (percent)	STAG/LOW Growth 1982-87: Annual growth rate (percent)	STAG/LOW Growth 1982-87: Share of growth (percent)	OPTIM/HIGH Employment 1987: Level (thousands)	OPTIM/HIGH Employment 1987: Distribution (percent)	OPTIM/HIGH Growth 1982-87: Annual growth rate (percent)	OPTIM/HIGH Growth 1982-87: Share of growth (percent)
Total major industries	707	831	64	3.3	82	925	65	5.5	77
Business services	189	217	17	2.8	18	229	16	3.9	14
Communications	43	46	4	2.5	4	51	4	3.5	3
Construction	48	45	3	-.3	--	53	4	1.7	2
Electrical machinery	153	188	14	4.2	22	210	15	6.3	20
Fabricated metals	82	106	8	5.2	15	127	9	9.0	16
Machinery, except electrical	112	142	11	4.8	19	136	9	3.9	8
Transportation equipment	80	85	7	1.4	4	119	8	8.2	14
All other industries	429	465	38	1.6	18	498	35	3.0	23

NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation.

over one-half the growth in engineering requirements between 1982-87. A third occupation which is highly sensitive to growth in defense spending is aeronautical/astronautical engineering. Although this occupation represented less than 6 percent of 1982 engineering employment, it is expected to account for nearly 14 percent of its growth over the subsequent 5-year period.

Electrical/electronic engineers. This occupation is the largest of the engineering specialties and, in 1987, is anticipated to provide between 395,000 and 420,000 job opportunities. The electrical machinery industry is the major employer of electrical/electronic engineers, but significant numbers of these personnel are also employed in business service, nonelectrical machinery, precision instruments, and communications industries.

This occupation is projected to be one of the fastest growing engineering fields, and shows a marked sensitivity to defense-expenditure assumptions. Requirements are expected to increase within the range of 3.9 percent to 5.1 percent per year over the analysis period indicating a likely increase over the 4.1-percent annual rate of employment growth recorded over the preceding 5-year period. In total, it is projected that there will be 70,000 to 95,000 additional jobs in this occupation between 1982 and 1987. Nearly one-half of these new jobs are expected to be concentrated in electrical and nonelectrical machinery industries; the business service and communications industries are projected to provide a significant share of those remaining.

Over the past several years, electrical/electronic engineering has been considered a potential shortage field, with demand exceeding the available supply of personnel. Alternative projections were compared to the ones reported here to determine the degree of consensus surrounding anticipated employment growth in this occupation.

In 1983, the Bureau of Labor Statistics (BLS) developed employment forecasts over the 1983-95 period as part of its medium-term occupational projection program. Using its own macroeconomic model and assumptions regarding social, political and economic development, an annual range of employment growth of roughly 4.5 percent was projected. The BLS projection scenarios assumed stronger economic growth in the period prior to 1990. Thus, the rate of increase of electrical/electronic engineers anticipated by BLS lies within, but at the high end of the range projected in this analysis.[7]

In 1980, the American Electronics Association (AEA) conducted an employer survey of 814 member firms requesting projections of requirements for these personnel through 1985. In "Technical Employment Projections of Professionals and Paraprofessionals," the AEA reported extrapolations of their survey results to the entire economy estimating a 12-percent annual rate of employment growth for electrical/electronic engineers (more than double that under the OPTIM/HIGH scenario). Employer projections are most accurate when based on orders and contracts in hand, generally for periods up to one year. Over longer periods, company plans tend to produce upwardly biased estimates of total employment for a variety of reasons. These include overly optimistic evaluations of future industry sales and company performance (especially during times of rapid growth), and the inability of individual companies to take account of the zero-sum adjustments that govern industry performance (within an industry, one company's gains are always at the expense of another).

Mechanical engineers. Mechanical engineering is the second largest engineering specialty. By 1987, requirements for personnel with such skills are expected to range from 225,000 to 250,000. Employment of these engineers is distributed across a broad spectrum of industries. The nonelectrical machinery and business service industries are the largest employers. Significant numbers of these personnel, however, can also be found in electrical machinery, fabricated metal, transportation equipment, and construction industries.

The broad industrial base providing job opportunities in this field generates an employment response across scenarios that is equally as sensitive to macroeconomic as it is to defense-expenditure assumptions. Between 1982 and 1987, the annual rate of growth in requirements for mechanical engineers is expected to range from 2.1 percent to 4.1 percent, generating a net increase of 20,000 to 45,000 job opportunities. This growth, if actualized, would represent an acceleration of the 2.0-percent annual growth rate in mechanical engineering employment recorded over the 1977-82 period. Growth in requirements reflect anticipated expansion of the machine tool industry, as well as changes in staffing patterns throughout the economy that reflect the need for additional personnel to operate increasingly complex industrial equipment.

Aeronautical/astronautical engineers. This occupation is highly specialized and plays an important role in industries involved in defense aircraft and missile systems, commercial aviation, and space exploration. Employment in this occupation is highly sensitive to defense programs and, because of these programs, is expected to be the most rapidly growing engineering specialty over the next five years. By 1987, requirements in this occupation are expected to range between 85,000 and 110,000. The annual rate of growth, ranging from 5.9 percent to 11.1 percent, is anticipated to generate an additional 20,000 to 45,000 jobs in this field over the 1982-87 period.

Other engineers. Employment in the remaining engineering specialties—civil, industrial, chemical, metallurgical, and mining/petroleum—is projected to grow faster than that of the overall work forces between 1982 and 1987. Taken individually, however, these occupations do not contribute significantly to the projected growth in engineering job opportunities.

In 1987, combined requirements in civil and industrial engineering occupations are projected to range between 295,000 and 320,000. Growth in requirements for these two occupations between 1982 and 1987 is expected to be limited by the industrial composition of these two work forces. In the case of civil engineering, major employment sectors—Government and the construction industry—are not expected to generate the expansion needed to sustain prior levels of employment growth. As for industrial engineering, the wide dispersion of this field's employment across industries reduces the ability of any one in particular to accelerate employment demand. A combined net increase of 23,000 to 55,000 jobs is anticipated for these occupations between 1982 and 1987.

Chemical, metallurgical, and mining/petroleum engineering occupations represent relatively few SET personnel, and, together are only projected to provide

[7] *Monthly Labor Review*, Vol. 106, No. 11, November 1983

between 105,000 and 110,000 job opportunities in 1987. Over the 5-year projection period, it is anticipated that the net growth in requirements in these specialties will range from 10,000 to 15,000.

technicians

As the data show, growth in demand for engineers and computer systems analysts has been closely paralleled by growth in requirements for technician personnel. These workers serve several important functions within the SET labor market. First, they provide highly specialized technical support to S/E personnel across the full spectrum of activities, including not only production, but also research and development. Second, technicians have, in the past, served an important role as an employment buffer when the supply of related S/E workers was inadequate to meet demand.

Over the past decade, however, this labor market has been coming into its own. The increasing technological complexity of industrial and research equipment is opening up many new job opportunities, and, at the same time, is requiring the acquisition of more specialized skills. The knowledge content of technician jobs has increased to the point where some degree of formal training is becoming the rule not the exception. Moreover, some technician occupations, such as computer programming and engineering technology, are requiring 4-year university or apprenticeship programs. The more rapid the job growth and the more specialized the training, the more inflexible is the supply of necessary personnel. For these reasons, the adequacy of the supply of personnel in these occupations has become an area of concern.

According to the projection scenarios, requirements for technicians are anticipated to reach 1,650,000 to 1,760,000 by 1987 (table 7). The business service industry, the major employer of S/E personnel, employs the largest share of these workers, providing one-fifth of technician job opportunities. Outside of this industry, however, employment of these personnel is widely dispersed across nonmanufacturing and manufacturing industries alike (table 8).

The dispersion of technician employment thoughout the economy makes the demand for these personnel responsive to both sets of assumptions underlying this analysis: general performance of the U.S. economy, as well as the level of defense expenditures. Between 1982 and 1987, requirements for these personnel are projected to increase within a range of 2.4 percent to 3.7 percent per year, a rate far in excess of total employment growth throughout the economy. Over the 5-year period, this growth implies a net addition of 185,000 to 295,000 job opportunities. The fast-growing business service industry is projected to provide the majority of employment growth in these occupations. A significant, but somewhat smaller share of new job openings is expected to be concentrated in the electrical and nonelectrical machinery industries.

Table 7. Projected employment in technician occupations: 1982-87

[In thousands]

Occupation	1982 employment	STAG/LOW 1987 employment	STAG/LOW Annual growth rate (percent)	OPTIM/HIGH 1987 employment	OPTIM/HIGH Annual growth rate (percent)
Total technicians	1,466	1,649	2.4	1,760	3.7
Computer programmers	235	290	4.3	300	5.0
Drafters	312	338	1.6	368	3.3
Electrical/electronic engineering	345	400	3.0	421	4.0
Industrial engineering	30	33	1.8	37	3.6
Mechanical engineering	45	50	2.5	57	5.0
Science/engineering, n.e.c.	498	536	1.5	576	2.9

NOTES: Because of rounding, components may not correspond to totals. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation

Table 8. Major industries determining projected level and growth in technician employment

Industry	1982 employment level (thousands)	STAG/LOW Employment 1987 Level (thousands)	STAG/LOW Employment 1987 Distribution (percent)	STAG/LOW Growth 1982-87 Annual growth rate (percent)	STAG/LOW Growth 1982-87 Share of growth (percent)	OPTIM/HIGH Employment 1987 Level (thousands)	OPTIM/HIGH Employment 1987 Distribution (percent)	OPTIM/HIGH Growth 1982-87 Annual growth rate (percent)	OPTIM/HIGH Growth 1982-87 Share of growth (percent)
Total major industries	905	1,054	63	3.1	82	1,109	63	4.1	69
Business services	320	375	23	3.2	30	396	22	4.4	26
Chemicals	48	52	3	1.6	2	53	3	1.9	2
Communications	50	54	3	1.4	2	55	3	1.9	2
Electrical machinery	112	136	8	4.7	18	152	9	3.4	8
Fabricated metals	44	49	3	2.3	3	59	3	5.9	5
Machinery, except electrical	123	155	9	3.9	13	146	8	6.2	13
Miscellaneous services	89	102	6	2.6	7	108	6	3.7	6
Wholesale and retail trade	119	131	8	1.9	7	140	8	3.4	7
All other industries	561	595	37	1.2	18	652	37	3.0	31

NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation

Computer programmers. Computer programming is projected to be one of the fastest growing of technician occupations. Responding to the increasing use of the computer both in business and in S/E applications, this occupation is expected to represent more than one-sixth of technician requirements by 1987 (chart 8). In that year, the projections indicate a level of requirements ranging from 290,000 to 300,000. The majority of these requirements will be in nonmanufacturing industries such as business services, finance, insurance, and real estate, miscellaneous services, and wholesale and retail trade. Within the manufacturing sector most of the requirements will be found in the durable-goods electrical and nonelectrical machinery industries.

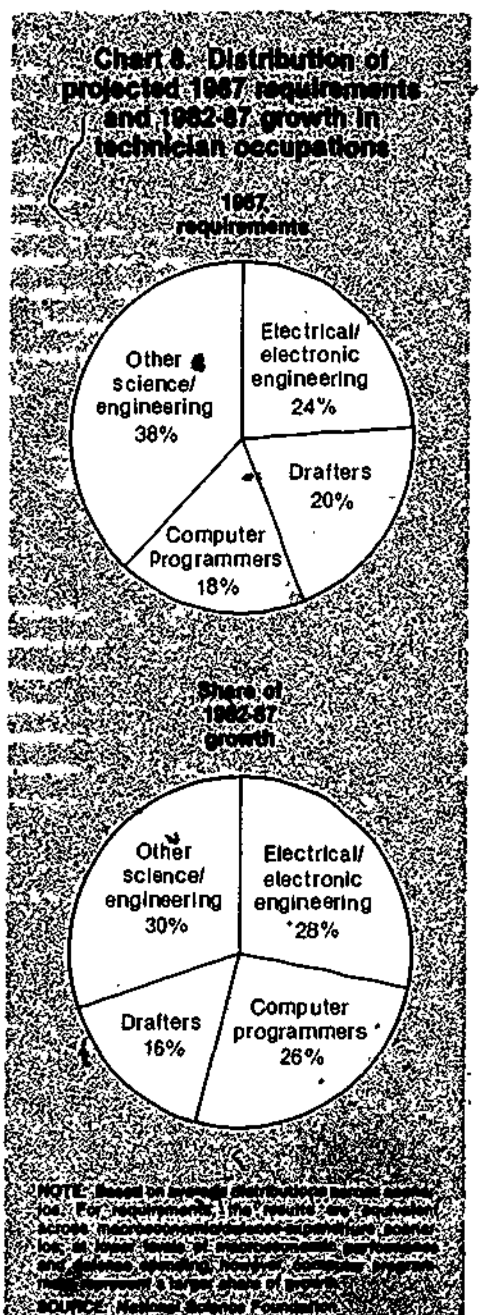


Chart 8. Distribution of projected 1987 requirements and 1982-87 growth in technician occupations

In the five years preceding 1982, the employment of computer programmers grew at an unprecedented rate of 13 percent per year. Occupational analysts have anticipated, however, that while employment growth in this occupation should remain strong, it nonetheless should moderate. This evaluation is based on the net effect of two trends—the increasing need for programmers as more industrial job functions are automated, and the reduction in requirements engendered by improvements in applications software that have made the computer accessible to other personnel.[18]

In keeping with these expectations, growth in requirements for computer programmers is projected to range from 4.3 percent to 5.0 percent per year betweeen 1982 and 1987, opening up an additional 55,000 to 65,000 jobs. Almost one-half of this employment growth is expected to be generated by business and miscellaneous service industries, primarily in R&D laboratories and establishments providing computer programming, management, and accounting services. Most of the remaining new job openings are expected to be found in the manufacturing sector, particularly in industries producing electrical machinery, nonelectrical machinery, and transportation equipment.

Drafters. Drafters account for roughly one-fifth of technician employment, providing assistance across a wide range of engineering and architectural specialties. These personnel are generally well-versed in mathematics, physical sciences, and manufacturing methods. By 1987, requirements for these workers are projected to range from 340,000 to 370,000. Most drafting job opportunities are expected to be found in the miscellaneous service industry, primarily in scientific, engineering, and surveying service establishments. A significant share of the remaining jobs is projected to be concentrated in large durable-goods manufacturing industries, including electrical and nonelectrical machinery and fabricated metal products.

The rate of employment growth in this occupation is projected to range from 1.6 percent to 3.3 percent per year over the 1982/87 period. During that time, an additional 25,000 to 55,000 drafting jobs are expected to open. Most of this projected growth in requirements will be concentrated within the business service industry, as well as in durable-goods manufacturing industries producing electrical and nonelectrical machinery.

Industrial growth and the increasing complexity of industrial design problems can be expected to contribute to sustaining growth in this field. It is believed, however, that new technologies such as computer-aided design and manufacture (CAD/CAM) may reduce the need for such personnel. If this be the case, growth rates lower than those projected may actually occur.

S/E technicians. The majority of technicians are employed in a variety of S/E subspecialties. Electrical/electronic engineering, mechanical engineering, industrial engineering, and S/E technicians, n.e.c. By 1987, requirements in these occupations are projected to reach 1,020,000 to 1,090,000. The majority of these workers are expected to be employed as electrical/electronic engineering technicians, or in the larger category, S/E technicians, n.e.c., that includes specialties in aeronautics, agriculture, biology, instrumentation, mathematics, meteorology, etc. In general, the employment environment of these technicians mirrors that of their S/E occupational counterparts with large numbers working in R&D laboratories and in major durable-goods manufacturing industries (electrical and nonelectrical machinery, chemicals, transportation equipment, etc.). A notable exception is the higher concentration of these workers in trade industries to perform sales and customer-related service functions.

Between 1982 and 1987, requirements in these occupations are anticipated to increase within a range of 2.1 percent to 3.5 percent per year, a rate of growth sufficiently strong to maintain the ranking of these specialties as a major source of employment growth throughout the economy. Over the 5-year projection period, 100,000 to 175,000 additional jobs are expected to be generated for these personnel. Major factors underlying this growth include industrial expansion, as well as changes in industrial staffing patterns mandated by the complexity of state-of-the-art industrial equipment and the adoption of automated industrial processes.

[18] Department of Labor, *Occupational Outlook Handbook*, op. cit.

III. the supply of SET personnel and labor market balance

labor supply model

In order to identify potential labor market imbalances, demand projections must be compared to estimates of the available supply of personnel. The occupational supply model chosen for this analysis represents the state-of-the-art. Developed under contract to NSF by Drs. Robert DauffenBach, Jack Fiorito, and Hugh Folk, the model was first used in the midseventies to assess the S/E labor market impact of Project Independence, a policy initiative directed toward national energy self-sufficiency. For purposes of this study, the model was updated to incorporate the most recently available data and to improve causal structure within certain of the model's subcomponents.[19]

general characteristics

The DauffenBach/Fiorito/Folk (DFF) model is unique in that it depicts the supply system for S/E personnel in 21 occupational categories representing computer specialties (systems analysis and programming), engineering, as well as mathematical, physical, and social sciences.[20] For each occupation, the model determines the supply of personnel in any given year from the supply in the preceding year adjusted to account for the net effect of worker flows into and out of that occupation.

The primary focus of the model is on the behavior that governs S/E personnel flows. These flows describe changes in supply that relate to three types of workers: New labor force entrants, experienced workers, and immigrants (chart 9). New labor force entrants, who have recently terminated their education to pursue full-time S/E employment are incorporated into the S/E supply as a result of the culmination of four decisions: (1) degree attainment, (2) curriculum choice, (3) labor force entry, and (4) occupational choice. A wide variety of factors influence the supply behavior of these workers including demographic trends, the availability of family income to finance college education, labor market conditions, and the compatibility of college coursework to occupational skill requirements. (See technical notes, "Stock Flow Model of Science and Engineering Labor Supply.") Experienced workers constitute the second category of personnel who affect overall supply. These workers provide a short-term flexibility to the S/E supply system that cannot be met through recent college graduates. Omitted from most supply analyses because of data, theoretical and methodological constraints, occupational mobility of the experienced work force is incorporated into the DFF model through estimates of personnel flows into, among, and out of S/E occupations; also included are flows out of the labor force that result from deaths and retirements. Experienced worker behavior in the model is determined primarily by job opportunities across various occupations as well as occupation-specific characteristics. The third category of worker affecting supply is immigrants whose behavior is affected by labor market conditions and immigration laws.

The feature of the DFF model that resulted in its selection for this study is

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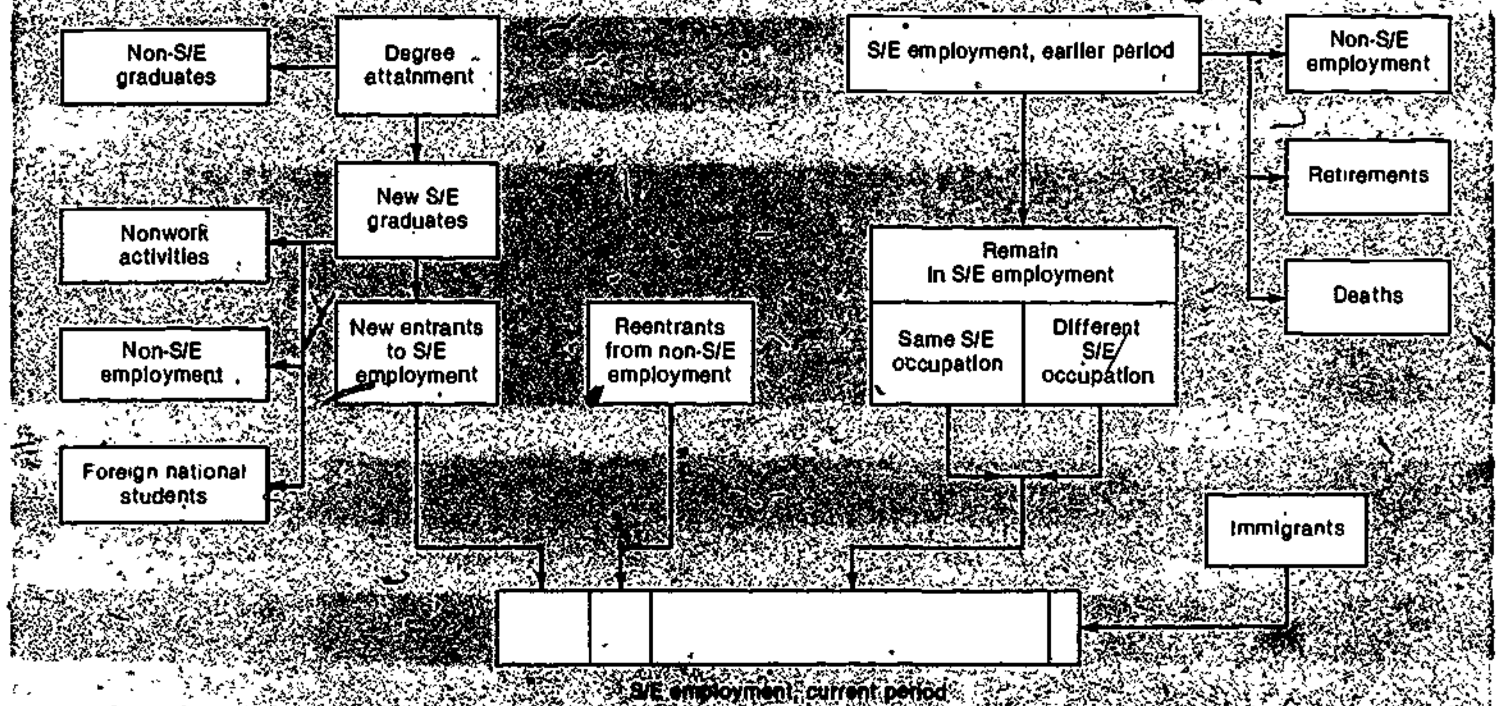
[19] The earlier model application can be found in R.C. DauffenBach, J. Fiorito, and H. Folk, "A Study of Projected Supply/Demand Imbalances of Scientific and Technical Personnel," Contract No. NSF C-SRS76-80591 (Stillwater, Okla. Oklahoma State University, 1980). Descriptions of revisions and more detailed findings from the current application are presented in R. C. DauffenBach and J. Fiorito, "Projections of Supply of Scientists and Engineers to Meet Defense and Nondefense Requirements, 1981-87," Contract No. NSF-C-SRS82-10548 (Stillwater, Okla. Oklahoma State University, 1983).

[20] Included are computer specialists (computer systems analysts and computer programmers), aeronautical/astronautical, chemical, civil, electrical/electronic, industrial, mechanical, metallurgical, mining, petroleum, and engineers, n.e.c., and mathematical, agricultural, biological, earth, other life and physical, and social scientists, n.e.c., as well as chemists, physicists, economists, psychologists, and sociologists.

Chart 8. Schematic diagram of the science and engineering (S/E) Dauffenbach/Fiorito/Folk labor supply model



SOURCE: Robert C. Dauffenbach and Jack Fiorito, Oklahoma State University

that the model can estimate supply response elicited by changing job opportunities. This response is especially critical in the face of rapid, short-term growth in requirements such as that anticipated under the defense buildup. For example, an increase in job opportunities within an occupation would induce more students to major in the related field and to seek jobs in the occupation upon graduation. Moreover, it would entice more experienced personnel to remain in, or transfer into, these jobs from other occupations and might permit immigrants with this occupational skill to enter the country under preferred-worker status. The DFF model depicts all aspects of this behavior. The market conditions used to drive the model were based on the four macroeconomic/defense-expenditure scenarios described in the preceding section; each projection scenario generated its own supply response.

alternative analyses of supply

Supply response restricted to new entrants and immigrants. The most frequently used methodology to assess potential market imbalances has been a form of analysis at the margin, i.e., for any given time period, an assessment as to whether the number of new S/E graduates and immigrants is adequate to fill the job openings generated by growth in requirements and attrition. This type of analysis considerably understates the flexibility of the S/E labor market by ignoring occupational mobility of the experienced work force. Nonetheless, the case can be made that, within the highly specialized S/E labor market, individuals with field-specific training may be best suited to fill requirements in any given field.[21]

One set of DFF model simulations replicated this form of marginal analysis. Growth in supply each year was determined by the net effect of labor force entry of college graduates and immigrants minus labor force departures resulting from deaths and retirements. Implicit to these simulations was the assumption that transfers into and out of S/E occupations by the experienced work force were equal. These simulations provided worst-case scenarios and were used to highlight those occupations most prone to supply shortages.

[21]More recent training in basic principles may make new entrants more fungible' giving the employer an opportunity to train a given job applicant in a number of fields outside their discipline of study. The occupational choice subcomponent of the DFF model permits such field switching.

Supply response including mobility. It is unlikely that personnel shortages will ever be reflected as unfilled job vacancies to the extent anticipated when supply adjustments are restricted to new entrants and immigrants. Labor markets will not tolerate prolonged imbalances and will quickly begin to make the adjustments needed to equilibrate the demand and supply of personnel. Employers can adjust to S/E supply imbalances by adjusting their hiring requirements.[22] For example, in cases of labor shortages, employers may use inexperienced, college graduates in higher than optimal proportions, they may upgrade technicians into formerly specified S/E job openings, or they may employ persons with S/E degrees and job experience in different fields from those in demand. The latter two types of adjustments are critical in determining the ability of the S/E labor force to meet short-term growth requirements. Both occupational transfers into and out of the S/E work force as well as those among S/E occupations can be explicitly accounted for by the DFF model.

To assess the full range of labor market dynamics, the full supply system was simulated without constraining to equality the flows of experienced workers into and out of the S/E jobs. Each year, new additions to supply were derived from the labor force entry of new college graduates and immigrants, as well as transfers from other occupations.

labor market balance in the early eighties

Before reporting findings about the projected balance of S/E supply and demand in 1987, it is useful to provide a point of reference on the degree of labor market balance at the start of the projection period. At the beginning of the eighties, the U.S. economy was weakened by persistent rates of high unemployment and inflation. Major sectors of the economy were showing signs of weakness in industrial output and productivity. During that period, only a few S/E occupations were of major concern to labor market analysts in terms of potential supply shortages. Among these occupations were computer fields—both systems analysis and programming—that had undergone rapid, unanticipated growth over the seventies and that promised to continue demanding high numbers of trained personnel. Also, among those occupations with potential supply problems were engineering fields. Certain specialties, such as electrical/electronic, computer, and petroleum engineering, were of concern because of rapid growth in demand. There were other indications of problems in engineering occupations, however. As faculty and graduate students were being lured from academia with the promise of higher salaries within industry and greater research opportunities, concern was being expressed that there would be inadequate numbers of professors to train future personnel.[23]

Various surveys and analyses of labor market conditions over this period provided corroborating evidence about the concerns being cited. An analysis over this period of labor market indicators (unemployment rates, relative wages, and occupational retention rates) conducted by BLS, indicated that the engineering job market was moderately tight.[24] Two NSF employer surveys resulted in similar findings. These surveys, designed to determine labor market conditions for new S/E graduates, indicated that as late as fall of 1981 industries were reporting shortages for computer scientists and systems analysts, as well as electrical/electronic and petroleum engineers. In addition, rough market balance was being reported in earth sciences, and in industrial, mechanical, and chemical engineering. By August, 1983, however, industrial employers were reporting no apparent shortages, but were anticipating a return to earlier rapid growth rates in the employment of both computer and electrical/electronic engineers. A relevant finding of these surveys to be subsequently addressed in more detail is that shortages do not have to be manifested in unfilled job vacancies. Many of those employers who reported shortages in the earlier NSF survey had, in fact, met their hiring goals, but were forced to incur the costs of increased recruitment efforts.[25]

general labor market conditions, 1987

Two concepts of labor market shortage are used in this analysis. The first concept deals with personnel shortages. These shortages are derived from the worst-case supply scenarios that assume all labor market adjustments were made through new labor force entrants and immigrants. It should be remembered that this analysis assumes that there was no net contribution to supply resulting from occupational mobility of the experienced work force.

This worst-case analysis is based on several assumptions about the degree of imbalance the labor market can support before problems are expected to develop. The first assumption is that shortfalls in projected supply of up to 5 percent would be tolerated as being sufficiently small so that nominal market adjustments could easily accomodate them. Occupations in which projected supply falls short of demand within the 5-percent to 10-percent range is considered to be of some concern with respect to the ability of the market to adjust by providing either adequate numbers of personnel and/or personnel of suitable training and experience. Market conditions in such occupations are judged to merit observation. Finally, if projected supply falls short of demand in an occupation by more than 10 percent, and if this shortfall is expected to be sustained, a serious shortage situation is indicated.

Despite the forced inflexibility of labor supply in these scenarios, the overall supply of S/E personnel is more than adequate to meet both growth in requirements and the replacement needs resulting from deaths and retirements (appendix tables B-9 to

[22]Employment requirements also adjust to the availability of supply. For example, employers can delay production, cancel orders, increase overtime, or adjust production techniques. These adjustments are extremely difficult to quantify and are not accounted for by this methodology. They are, however, considered secondary to the response of supply to changes in demand requirements.

[23]National Science Foundation, "Engineering Colleges Report 10% of Faculty Positions Vacant in Fall 1980," *Science Resources Studies Highlights* (NSF 81-332) (Washington, D.C., November 2, 1981), and Business-Higher Education Forum, *Engineering Manpower and Education: Foundation for Future Competitiveness* (Washington, D.C.: American Council on Education, October 1982).

[24]D. Braddock, "The Job Market for Engineers: Recent Conditions and Future Prospects," in *Occupational Outlook Quarterly*, Summer 1983.

[25]National Science Foundation, "Labor Markets for New Science and Engineering Graduates in Private Industry," op. cit. and "Industry Demand for Scientists and Engineers Still Slack in Mid-1983," Division of Science Resources Studies *Preview*, November 1983.

B-12). All science occupations show substantial personnel surpluses in 1987. Engineering occupations are much closer to being in balance, however, although some specialties are projected to have shortages of personnel. Shortages are indicated for both aeronautical/astronautical and electrical/electronic engineering occupations. Among the remaining specialties, industrial and mechanical engineering appear to be in rough balance, all other engineering fields are projected to have personnel surpluses. According to these scenarios, the largest shortage of personnel is in computer specialty fields (table 9).

The second concept of personnel shortage, quality of the work force, is used to analyze results from the full supply system model that includes market-sensitive occupational mobility. With occupational mobility taken into account, no S/E occupation is characterized by market imbalance under the criteria set earlier (appendix tables B-17 to B-20). The adjustments within the S/E labor market that are needed to meet growing requirements, however, suggest a problem seldom considered explicitly in studies of demand/supply balance. That problem is whether large market adjustments can be sustained while fully meeting the requirements for specialized S/E personnel in terms of quality. As stated in the report prepared by Drs. Robert DauffenBach and Jack Fiorito, market-sensitive mobility, "... necessitates an adjustment in how we think about shortages and surpluses."[26] It is important to realize that economic efficiency and labor market performance are not necessarily maximized when supply and demand are in balance. Such maximization is only achieved when requirements are filled with *experienced and appropriately trained* personnel, unless these criteria are met, the general quality of the work force will be diminished. Use of inappropriately trained workers is, in itself, a manifestation of labor market shortage.

Over a relatively short period of time, S/E labor market adjustments are achieved primarily through occupational mobility and, to a lesser extent, through the increased use of S/E college graduates and immigrants. The DFF model provides valuable insight into the magnitude and, hence, feasibility of projected adjustments that must be made within the S/E labor market to meet both growth and replacement needs.

[26] R C DauffenBach and J Fiorito, Projections of Supply of Scientists and Engineers . op. cit

Table 9. Projected science/engineering labor market balance: 1987

	New entrants and immigrants sufficient to meet growth in requirements	Occupational mobility needed to meet growth in requirements[2]	
		High rate of in-mobility	Low to moderate rate of in-mobility
		Shortage	Potential shortage
Computer specialists[1]		•, +	
Scientists:			
Agricultural	•, +		
Biologists	•, +		
Chemists	•, +		
Geologists	•, +		
Mathematical	•, +		
Physicists	•, +		
Social	•, +		
Engineers:			
Aeronautical/astronautical		•, +	
Chemical	•, +		
Civil	•, +		
Electrical/electronic	•		+
Industrial	•, +		
Mechanical	•, +		
Metallurgical	•, +		
Mining/petroleum	•, +		
Engineers, n.e.c.	•, +		

[1] Includes both computer systems analysts and programmers

[2] Supply of new entrants and immigrants is considered insufficient to meet growth in requirements if supply estimates fall short of projected requirements by more than 5 percent

NOTES A "•" denotes findings based on the STAG/LOW scenario; a "+" denotes those based on OPTIM/HIGH. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE National Science Foundation

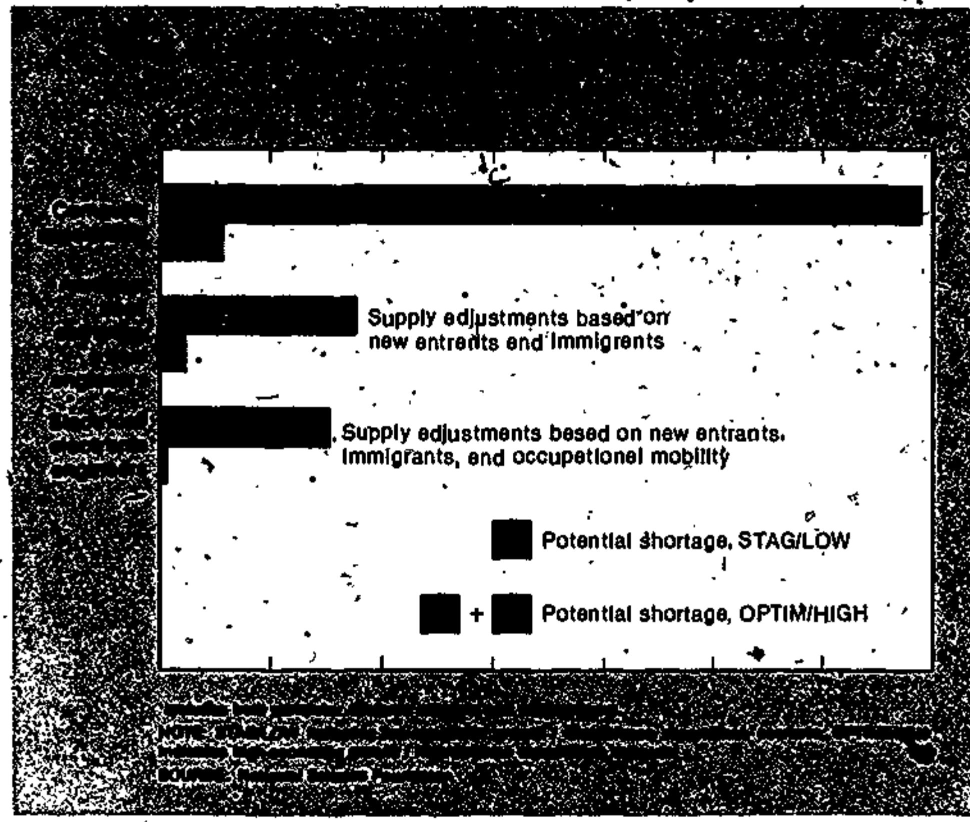
projected shortage fields, 1987

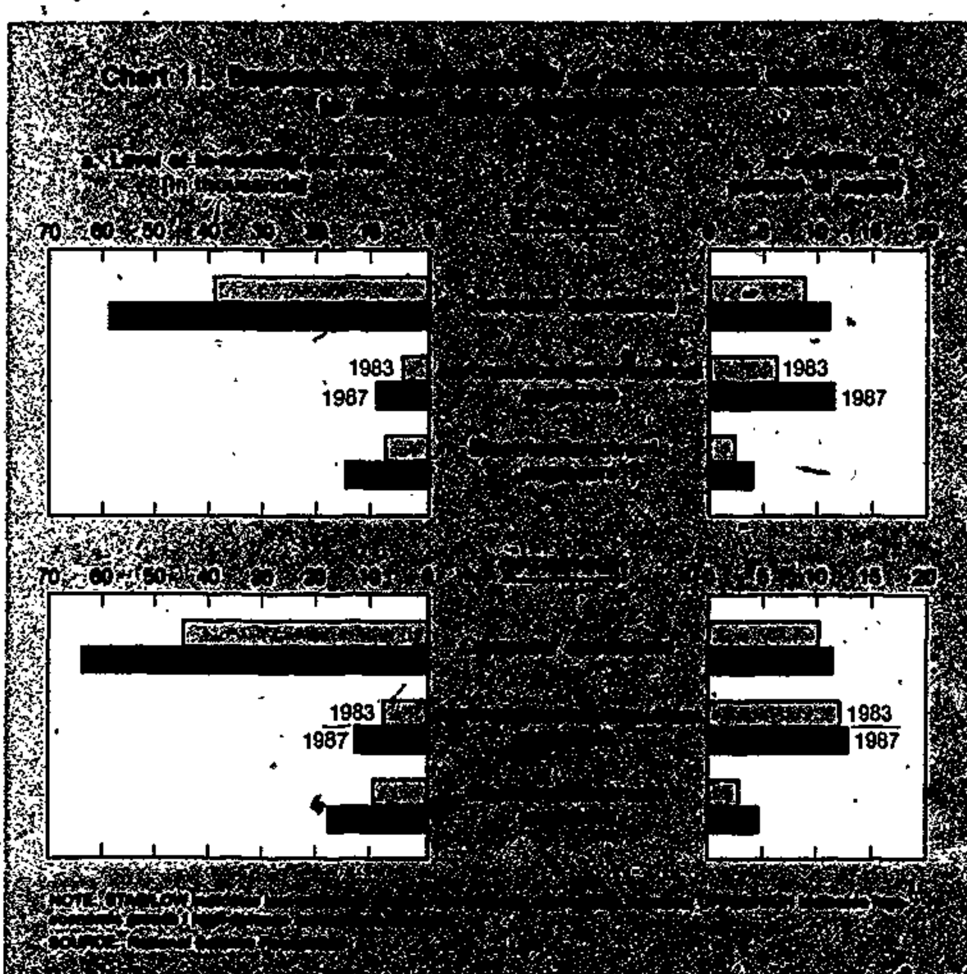
Aeronautical/astronautical engineers. Employment in this engineering specialty was projected to increase at an average annual rate ranging from 5.9 percent to 11.1 percent between 1982 and 1987. Growth in this occupation is expected to outpace additions to supply from new entrants and immigrants, indicating a shortage situation regardless of the levels of defense and nondefense demand being simulated. While available supply of personnel in this occupation appeared to exceed demand in 1982, by 1987 shortages are projected to range from 15 percent in STAG/LOW to 45 percent in OPTIM/HIGH, suggesting the need for an additional 10,000 to 35,000 personnel (chart 10).

The high concentration of aeronautical/astronautical engineers in relatively few industries would suggest that personnel shortages could lead to salary escalation, production delays, or other employer-oriented demand adjustments, within-industry competition could also arise between commercial and defense production. Employment in this occupation is highly sensitive to cyclical swings in industrial performance. Therefore, cancellation of major air systems or sustained depression in the demand for commercial aircraft could rapidly alleviate a shortage situation.

Occupational mobility within the experienced work force can also be expected to alleviate potential personnel shortages when inadequate numbers of new labor force entrants and immigrants are available to meet both growth and replacement needs. When mobility is taken into account, potential shortages decline dramatically. For the STAG/LOW and OPTIM/HIGH scenarios, the shortage of aeronautical/astronautical engineers in 1987 ranges from 2.3 percent to 4.2 percent of supply and represents only 2,000 to 4,500 personnel. In that year projected supply growth under the STAG/LOW scenario is comprised of roughly 9,000 experienced workers entering from other occupations, 2,000 new entrants, and 100 immigrants; the comparable figures for the OPTIM/HIGH scenario are 13,000, 2,000, and 200, respectively (appendix tables B-13 to B-16).

The number of workers entering aeronautical/astronautical engineering from other occupations grows continually over





the projection period reaching 1[illegible] percent to 1[illegible] percent of supply by 1987 (chart 11). Such sustained high rates of in-mobility could not be maintained without affecting the quality of this work force as greater numbers of inappropriately trained personnel are asked to perform these job functions.

In-mobile workers can be expected to come from both other S/E occupations and, to a lesser extent, from non-S/E fields. In the case of the former, workers can be considered somewhat interchangeable because of common training in basic principles. Nonetheless, some time will be required to gain relevant experience in the new field. As an example, at Wright-Patterson Air Force Base military personnel who were trained in physics, mechanical engineering, and electrical engineering are retrained as aeronautical engineers to help alleviate problems in recruiting and retention in this specialty. These programs last 18 months, [illegible] months, and 9 months, respectively, and even after such training is completed, functional level in the new field is considered to be entry level. Thus, extensive formal or on-the-job retraining to meet rapid employment growth can result in substantial costs and production delays while still producing workers with insufficient work experience in the new field.[27]

In-mobile workers can also be drawn from non-S/E fields during periods of extraordinarily high demand and include, for example, technologists and other non-S/E graduates. This behavior was evidenced in the engineering market during the fifties and early sixties when defense and space programs generated a rapid growth in demand for engineering skills. During this period, it was estimated that nondegreed personnel constituted as much as 25 percent of employed engineers.[28] Excessive reliance

[27]Based on findings from Department of Aeronautics and Astronautics, Air Force Institute of Technolgy, Wright-Patterson Air Force Base P. Torv[illegible] and R. Fontana, "Ab Engineering Program for Science Graduates," Proceedings North Central Section, American Society for Engineering Education (Dayton, Ohio, April 23-25, 1981).

[28]Based on 1958 data Of those workers employed in engineering without a bachelor's degree, two-thirds reported having one to three years of college, one fifth reported only to have graduated from high school, and one-eighth reported to have less than high-school training National Science Foundation, *Characteristics of Men Employed in Engineering Jobs in the United States in 1958* (Washington, D.C., 1963)

on such personnel also exacts costs and is an inadequate long-term solution to shortages of appropriately trained workers.

Rapid employment growth in an occupation can also be expected to exert pressure on academic institutions. According to supply projections, the number of new aeronautical/astronautical engineering graduates entering the labor force between 1982 and 1987 would increase by 1.6 percent per year under the STAG/LOW scenario and as much as 3.8 percent per year under OPTIM/HIGH. Accelerated growth in new labor force entrants over a relatively short 5-year period can be achieved in either of two ways. First, students already in the pipeline can be encouraged to change majors, potentially straining the available academic capacity to produce such engineers, or, second, as was evidenced in engineering occupations during the tight labor market of the late seventies and early eighties, students could be enticed to forego advanced degrees so as to capitalize on strong job opportunities. This latter behavior could reduce the quality of workers with respect to formal training. More importantly, however, it could also jeopardize the future supply of faculty needed by academia.[29]

Computer specialists. According to NSF taxonomy, computer analysts and computer programmers are representative of science and technician occupations, respectively. Data needed to estimate the supply model, however, could not be disaggregated to differentiate between these two specialties, they were therefore combined for the analysis of labor market balance. Requirements for this combined occupation are expected to grow at an annual rate ranging from 4.9 percent to 5.8 percent over the projection period. Regardless of scenario, growth in the supply of new labor force entrants and immigrants is projected to fall behind that of demand, thereby leading to an increasing shortage in the years ahead. By 1987, the projected supply shortfall ranges from 15 percent in STAG/LOW to 30 percent in OPTIM/HIGH, generating the need for an additional 115,000 to 140,000 personnel.

As with the aeronautical/astronautical engineering occupation, computer systems analysis and computer programming require large inflows of personnel to meet growing demand. Under the STAG/LOW and OPTIM/HIGH scenarios, computer specialty fields receive a dramatic infusion of workers from other occupations, reducing personnel shortages to within a range of only 1.6 percent to 1.8 percent in 1987, roughly 9,000 to 11,000 workers. Labor market dynamics depicted by the DFF model show that 1987 increments to supply in the STAG/LOW scenario are projected to include 59,000 in-mobile workers, 13,000 new labor force entrants, and over 1,000 immigrants. The stronger growth in requirements under the OPTIM/HIGH scenario generates adjustments of 64,000, 14,000, and 1,200, respectively.

In-mobility plays an important role in computer specialty occupations over time to meet growth in requirements over the projection period. By 1987, workers entering from other occupations would represent roughly 11 percent of total supply. Traditionally, computer occupations have been very flexible in terms of accepting workers from other fields. It must be kept in mind, however, that business and S/E applications in these occupations cannot be differentiated with existing data, and both differ significantly with respect to background training. Personnel working on S/E applications are generally expected to have a strong foundation in principles of physical sciences, mathematics, and engineering fields; for more complex applications, graduate degrees are becoming increasingly common. Therefore, if rapid growth occurs in S/E-application systems analysis and programming, continued high transfer rates from other occupations may be difficult to sustain. This will be especially true as more advanced applications are introduced in areas such as CAD/CAM, information technology, telecommunications, and the sophisticated modeling encouraged by the development of the supercomputer.

Electrical/electronic engineers. Employment of these engineers is expected to increase at an average annual rate ranging from 3.9 percent to 5.1 percent between 1982 and 1987. Projected increments to supply based on new labor force entrants and immigrants are adequate to balance projected employment in this field at low levels of defense spending. Under assumptions of high defense expenditures, however, supply may be barely adequate; by 1987, a potential shortage of up to 30,000 personnel could arise if assumptions made under the OPTIM/HIGH scenario are met.

When occupationally mobile workers are included as a source of supply, however, the high level of demand for this specialty induces a positive net inflow of personnel. By 1987, labor market balance is indicated across all scenarios, with OPTIM/HIGH scenario showing a moderate surplus of almost 1,000 workers. Additional employment requirements generated in the last projection year under this scenario elicit a supply response of 18,700 in-mobile experienced workers, 15,700 new entrants, and 1,200 immigrants. While the rate of in-mobility required to alleviate potential personnel shortages are not as high as those required for aeronautical/astronautical engineers or computer specialists, they do rise over time reaching almost 5 percent of requirements.

potential supply constraints in technician occupations

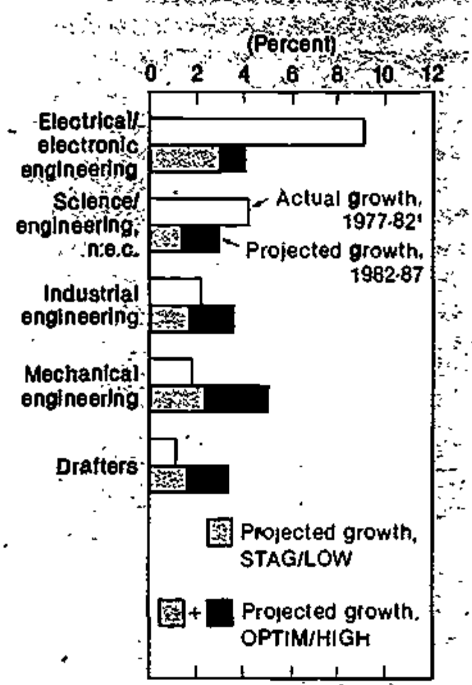
The supply of technicians is difficult to measure because formal training cannot be used as a means of identifying the population available to fill these jobs. For these occupations, there is no model of supply comparable to that developed for the S/E work force. In order to identify potential supply constraints, it was assumed that growth in requirements, much in excess of those attained in the recent past, would likely result in labor market adjustment problems. Thus, actual employment growth rates for 1977-82 were compared to projected growth rates in requirements for 1982-87.

Three technician occupations—drafters, mechanical engineering, and industrial engineering—are characterized by an accelerated growth in projected requirements (chart 12).[30]

[29]Over longer periods of time, academic institutions may be ill-equipped to increase enrollments to levels projected in the model. The model cannot account for institutional constraints of this nature.

[30]The Current Population Survey (CPS) which was used to derive the actual 1977-82 employment growth rates contains few people categorized as mechanical or industrial engineering technicians. Growth rates are, therefore, extremely variable and should be interpreted with caution.

Chart 12: Projected versus actual employment growth in technician occupations



[1]Based on Department of Labor's Current Population Survey (CPS).

NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

SOURCE: National Science Foundation

In all three cases, there were individual years within the 1977-82 period when growth rates as high as those projected were achieved. A problem arises, however, from the fact that the projected increases in requirements for 1982 to 1987 are dramatic when taken in the context of the sharp recession-induced reductions in employment at the start of the decade. The likelihood of future shortages, therefore, will be a function of both the ability of employers to attract new workers to these occupations, as well as the increasing amount of time needed for training because of the growing technological complexity of the workplace.[31]

conclusions

The principal conclusion of this analysis is that strong growth in demand is projected to create problems in three S/E occupations computer specialties, which have had a relatively tight labor market over the past decade, and aeronautical/astronautical and electrical/electronic engineering, both of which are expected to be seriously affected by the level and pattern of the defense buildup. Some attention should also be given to those technician occupations—drafters, mechanical, and industrial engineering—for which the projected growth in requirements is expected to accelerate in the years ahead.

Despite the high levels of skill required in these fields, labor market adjustments are likely to be made, even over a relatively short 5-year period, moderating identifiable personnel shortages that could potentially be manifested as job vacancies. The process by which the labor market equilibrates demand and supply, however, can be expected to have an impact on the quality of the SET work force. The larger the required adjustment, the more likely it is that employers would be forced to hire individuals with inappropriate training and/or experience. Such quality downgrading is, itself, a manifestation of labor market imbalance and can impose very real costs not only in terms of employer-supplied training, but more importantly in terms of productivity and quality losses. These effects can significantly hinder national programs such as the defense buildup. Finally, the costs of current market adjustments can have an impact on future S/E labor supply if the academic sector fails to retain graduate students or current faculty.

[31]It is anticipated that computer aided design and manufacture (CAD CAM) will reduce the need for drafters. Should this be the case, actual employment growth may be lower than that projected. G. Belinsky, "CAD/CAM: The Industrial Revolution," *TWA Ambassador*, July 1982.

appendixes

a. technical notes

projection models

defense interindustry forecasting system (DIFS): employment projections

dauffenbach/fiorito/folk (dff) model: stock-flow model of science and engineering labor supply

b. detailed statistical tables

appendix a

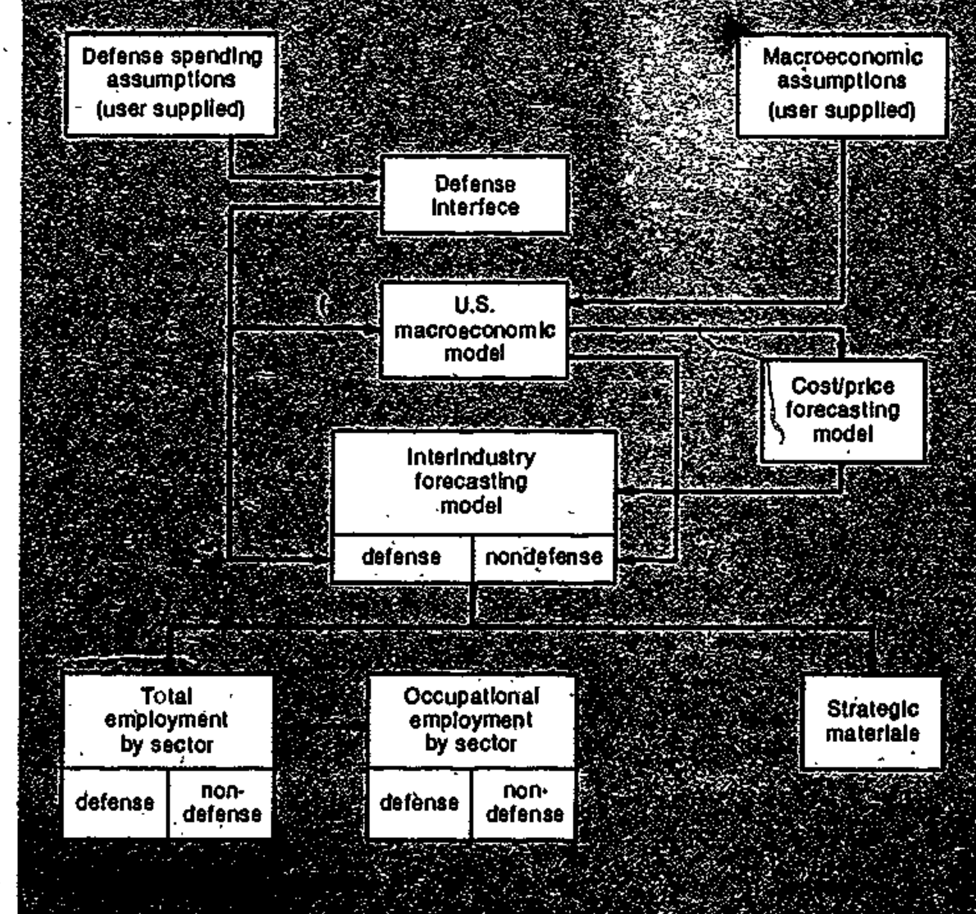
technical notes

projection models

defense interindustry forecasting system (DIFS): employment projections

The Defense Interindustry Forecasting System (DIFS), a collaborative modeling effort undertaken by Data Resources, Incorporated (DRI) and the Department of Defense (DOD), was used to generate the employment projections presented in this analysis.[1] Built around the DRI macroeconomic forecasting model, the DIF System can estimate total occupational requirements under varying assumptions about the operations of the full economy. In addition, the system's defense interface permits the integration of detailed defense expenditure information making possible an analysis of the expected impact of alternative defense budgets on key industries, skilled labor, and raw material categories. The general structure of the system is depicted in chart A-1; a description of basic model components follows.

Chart A-1. Simplified diagram of the Defense Interindustry Forecasting System (DIFS)



[1] The DIF System is maintained and marketed by DRI. The Office of the Assistant Secretary of Defense, Department of Defense, maintains its own version under the name of the Defense Economic Impact Modeling Sytem (DEIMS). For more complete documentation see David L. Blond, "Defense Economic Impact Modeling System" (Washington, D.C.: Department of Defense, July 1982) and Data Resources, Incorporated, "Selected Examples from DRI's Defense Economic Service" (Washington, D.C., 1982).

defense translator and interface

The defense translator provides for the translation of defense planning into a framework consistent with the U.S. Macroeconomic and Interindustry Forecasting Models. The interface starts with DOD's five-year defense plan (FYDP) which is presented in terms of total obligation authority (TOA), a constant-dollar measure of the cost to complete anticipated procurements. The impact of the FYDP on the economy, however, occurs only when actual contracts and expenditures are made. A TOA-to-Outlay Translation Model is therefore needed to convert the planning budget as defined for 50 budget accounts into outlays per year[2] These, in turn, are combined with expenditures authorized in earlier years Once total defense expenditures by budget category are obtained, a Defense Industrial Share Matrix is used to translate expenditures into final demand by commodity This share matrix, developed by DOD, represents the unique pattern of defense final demand by 4-digit Standard Industrial Classification (SIC) groups.

Once final demand is allocated by SIC group, the Defense Interface is used to ensure that changes in industrial composition generated by the defense budget are accounted for in the macroeconomic model. To do this, a preliminary pass of the macroeconomic model is made with the specified pattern of defense final demand in order to adjust those model factors that define national industrial production.

macroeconomic model

The DIF System is built around DRI's Quarterly Model of the U.S. Economy, one of the major, large-scale econometric models used for forecasting and policy evaluation.[3] Fifty exogenous variables are available for use in defining various economic scenarios. These variables fall into six categories. Fiscal policy, monetary policy, energy, agricultural prices, foreign economic activity, and demographic trends The 1,200 equations of the model define the behavior of major components of gross national product (GNP), Federal, State, and local Government sectors; international trade; wages and prices; employment; financial markets; and industrial production.[4] Within this model, the impact of the levels and patterns of defense and nondefense activities on industrial production are estimated.

interindustry model

The interindustry model is a dynamic input/output (I/O) model that determines direct and indirect industrial production in both defense and nondefense sectors of the economy. The I/O coefficients used at the time of this analysis were based on the 1972 400-commodity, benchmark tables published by the Bureau of Economic Analysis of the Department of Commerce. These coefficients were updated to 1978 using an econometric technique that modifies production coefficients to account for the influence of both long-run economic trends and business cycles. For subsequent years, coefficients were forecast to reflect shifts in industrial structure that occur in response to changes in prices (determined in the Price Forecasting Model) and technology.

total employment model

Production as determined in the I/O model, is translated into estimates of total industry employment through a series of production equations that relate levels of industrial output to labor input and a trend variable that serves as a proxy for both changes in productivity and growth in capital stock. These equations imply a desired employment level corresponding to given levels of output. Actual employment is then derived using a partial adjustment mechanism that accounts for delays in moving to desired employment levels until output changes are recognized as permanent.

occupational employment by industry

Total industry employment is distributed across occupations based on staffing patterns derived from the Occupational Employment Statistics (OES) matrix developed by the Office of Economic Growth and Employment Projections of the Bureau of Labor Statistics (BLS).[5] At the request of the National Science Foundation (NSF), BLS provided DRI with two matrices for this analysis: One depicts actual data for 1978, the other presents projected 1990 staffing patterns that reflect anticipated changes in industrial occupational requirements expected to result from changes in technology and product mix. Linear interpolations of these matrix coefficients were used to determine industrial staffing needs in interim years. Staffing patterns for 84 aggregated industries were used in this analysis. A listing of these industries is presented in table A-1.

Table A-1. Major industrial groupings used for analysis

Industry	Related Census-SIC codes, 1972 edition
Agriculture, forestry, and fisheries	
Livestock and livestock products	part 01, part 02
Other agricultural products	part 01, part 02
Forestry and fishery products	081-4, 091, 097
Agriculture, forestry, and fishery services........	0254, 07 (excluding 074), 085, 092
Mining	
Iron and ferroalloy ores mining	101, 106
Nonferrous metal ores mining	102-5, part 106, 109
Coal mining	1111, part 1112, 1211, part 1212
Crude petroleum and natural gas	131, 132, part 138
Stone and clay mining and quarrying	141-5, part 148, 149

[2]The 50 defense budget categories fall under five major account headings military personnel, operations and maintenance, procurement, research, development, testing, and evaluation, and military construction.

[3]Otto Eckstein, *The DRI Model of the U.S. Economy* (New York McGraw-Hill Book Company, 1983).

[4]The Quarterly Model is updated biannually The model version used in this analysis was that in operation as of July 1982, this version incorporated the major changes in tax policy initiated by the Reagan Administration and passed by the Senate in the summer of 1982.

[5]The OES matrix is the basis of employment projections derived by BLS A description of the data, as well as BLS employment projections can be found in *Monthly Labor Review*, Vol 106, No 11, November 1983

Table A-1. Major industrial groupings used for analysis—Continued

Industry	Related Census-SIC codes, 1972 edition
Chemical and fertilizer mineral mining	147
Construction	
New construction	part 15-17, part 108, part 1112, part 1212, part 148
Maintenance and, repair construction	part 15-17, part 138
Food and kindred products	20
Tobacco manufactures	21
Textiles and apparel	
Fabric, yarn, and thread mills	221-4, 226, 228
Miscellaneous textile goods and floor coverings	227, 229
Apparel	225
Miscellaneous fabricated textile products	239
Lumber products	
Lumber and wood products, except containers	241-3, 2448, 249
Wood containers	2441, 2449
Household furniture	251
Other furniture and fixtures	252-4, 259
Paper and allied products	
Paper and allied products, except containers	261-4, 266
Paperboard containers	265
Printing and Publishing	27
Chemicals and allied products	
Chemicals and selected chemical products	281, 286-7, 289
Plastics and synthetic materials	282
Drugs, cleaning, and toilet preparations	283-4
Paints and allied products	285
Petroleum refining and related industries	29
Rubber and miscellaneous plastic products	30
Leather products	
Leather tanning and finishing	311
Footwear and other leather products	313-7, 319
Stone, clay, and glass products	
Glass and glass products	321-3
Stone and clay products	324-9
Primary metals	
Primary iron and steel manufacturing	331-2, 339, 3462
Primary nonferrous metals manufacturing	333-6, 3463
Fabricated metals	
Ordnance and accessories	3482-4, 3489, 3761, 3795
Metal containers	341
Heating, plumbing, and structural metal products	343-4
Screw machine products and stampings	345, 3465-6, 3469
Other fabricated metal products	342, 347, 349
Machinery, except electrical	
Engines and turbines	351
Farm and garden machinery	352
Construction and mining machinery	3531-3
Materials handling, machinery, and equipment	3534-7
Metal working machinery and equipment	354
Special industry machinery and equipment	355
General industrial machinery and equipment	356
Office, computing, and accounting machines	357
Service industry machines	358
Miscellaneous machinery	359
Electrical machinery	
Electrical transmission and distribution equipment and industrial apparatus	361-2, 3825
Household appliances	363
Electric wiring and wiring equipment	364
Radio, TV, and communication equipment	365-6
Electronic components and accessories	367
Miscellaneous electrical machinery, equipment, and supplies	369
Transportation equipment	
Motor vehicles and equipment	371
Aircraft and parts	372
Other transportation equipment	373-5, 3792, 3799, 2451
Precision instruments	
Professional, scientific, and controlling instruments and supplies	381, 3822-4, 3829, 384, 387
Optical, ophthalmic, and photographic equipment and supplies	383, 385-6
Miscellaneous manufacturing	39
Transportation, communication and utilities	
Transportation and warehousing	40-2, 44-7
Communications, except radio and TV	481-2, 489
Radio and TV broadcasting	483
Electric, gas, water, and sanitary services	49
Wholesale and retail trade	50-7, 59, 7396, 8042
Finance, insurance, and real estate	
Finance and insurance	60-4, 67
Real estate and rental	65-6, part 1531
Other services	
Hotels and lodging, personal and repair services	70-2, 762-4, part 7699
Eating and drinking places	58
Automobile repair and services	75
Amusements	78-9
Business services	73 (excluding 7396), 7692, 7694, part 7699
Health, educational, social services, and nonprofit organizations	74, 80 (excluding 8042), 82-4, 86, 8922
Government	
Federal Government enterprises	Not applicable
State and local government enterprises	
Government industry	
Other	
Noncomparable imports	Not applicable
Scrap, used, and second-hand goods	
Rest of the world industry	
Household industry	

dauffenbach/fiorito/folk (DFF) model: stock-flow model of science and engineering labor supply

The DauffenBach/Fiorito/Folk model is the most comprehensive model of S/E labor supply available. The supply system of S/E personnel depicted by the model consists of four major distinct-but-related components including: (1) the existing stock of S/E personnel; (2) flows of new entrants to S/E occupations; (3) flows of experienced workers into, among, and out of S/E occupations; and, (4) international flows of S/E workers (chart A-2). The model attempts to capture, to the extent permitted by data availability and compatibility, the complex behavioral relationships that generate the flows of personnel into and out of this labor market.

The model provides estimates of the supply of S/E personnel in 21 detailed occupations (table A-2). Supply in each year is determined by the previous year's stock adjusted for the three major flows detailed above. Each of these flows is related to projected labor market conditions in the various occupations under the assumption that supply responds to changes in demand. For this study, projected market conditions were based on the four macroeconomic/defense-expenditure scenarios generated by DRI's DIFS. Thus, four sets of supply estimates were generated—one for each demand scenario.

The remainder of this section closely follows the structure of the model and is designed, in part, to provide an appreciation of the complexity of modeling the S/E supply system. The description of each model component highlights those factors which determine supply behavior.[6]

[6]A thorough discussion of the theory underlying the model, as well as its estimation can be found in two reports. Robert C. DauffenBach and Jack Fiorito, *Projections of Supply of Scientists and Engineers to Meet Defense and Nondefense Requirements, 1981-87*. NSF Contract No SRS-8210548 (Stillwater, Okla.: College of Business Administration, Oklahoma State University, April 1983) and Robert C. DauffenBach, Jack Fiorito, and Hugh Folk, *A Study of Projected Supply/Demand Imbalances for Scientific and Technical Personnel*. NSF Contract No. SRS-7680591 (Stillwater, Okla.: College of Business Administration, Oklahoma State University, 1980)

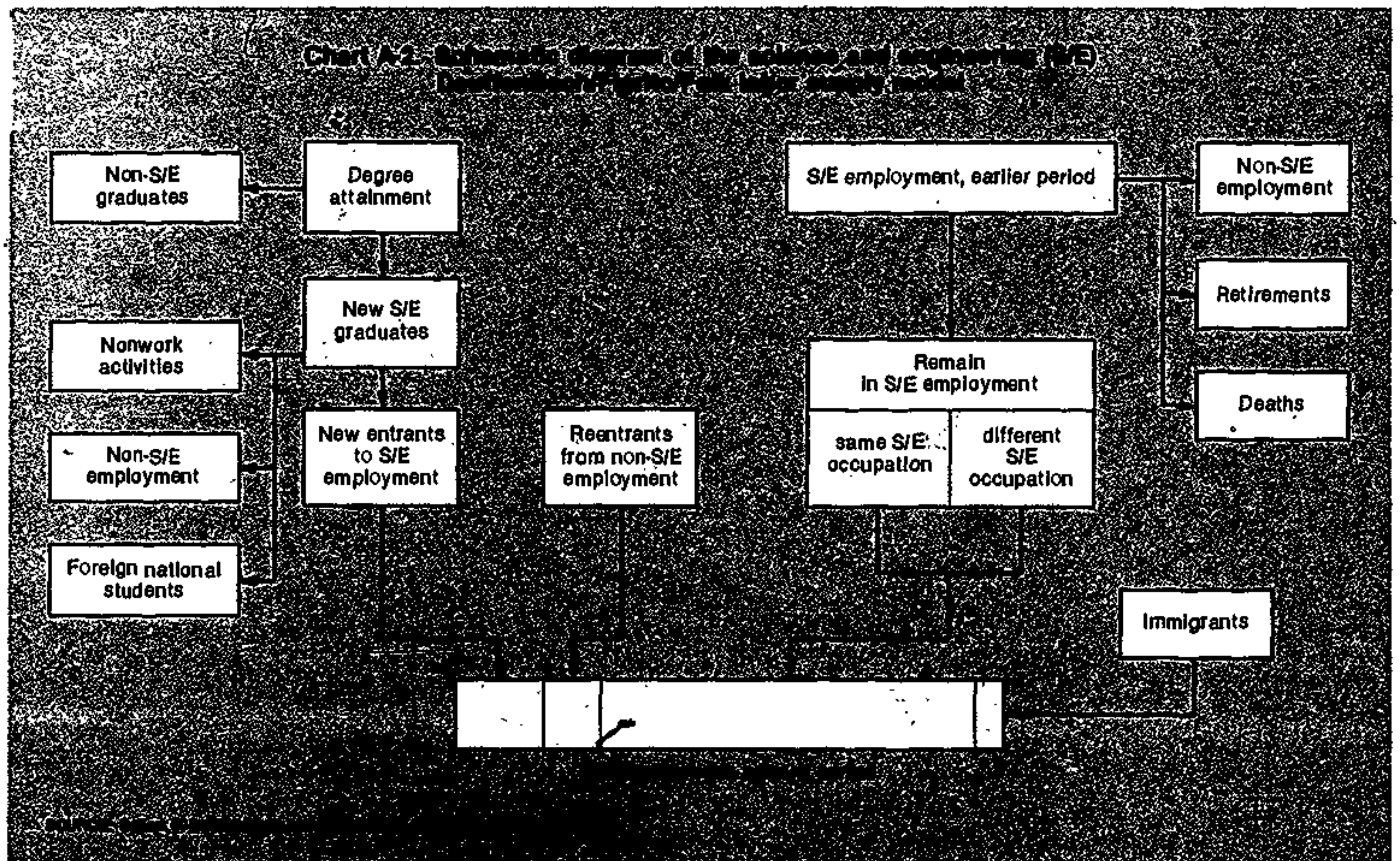


Table A-2. Occupational taxonomy used in the DauffenBach/Fiorito/Folk supply model

Occupation	1970 Census 3-digit occupational categories	Occupational Employment Statistics (OES) matrix categories
1. Aeronautical/astronautical/ engineers	006	10020200 (aeronautical/ astronautical)
2. Chemical engineers	010	10020400 (chemical) 10020402 (ceramic)
3. Civil engineers	011	10020600 (civil)
4. Electrical/electronic engineers	012	10020800 (electrical/electronic) 10022004 (nuclear)
5. Industrial engineers	013	10021000 (industrial) 10021002 (safety)
6. Mechanical engineers	014	10021200 (mechanical) 10021202 (marine)
7. Metallurgical/materials engineers	015	1002[illegible]00 (metal)
8. Mining/petroleum engineers	020 (mining) 021 (petroleum)	10021600 (mining) 10021800 (petroleum)
9. Other engineers	022 (sales) 023 (n.e.c.)	10022000 (other) 10022003 (traffic) 10022005 (agriculture) 10022001 (engineer) 10022099 (other)
10. Computer specialists	003 (programmer) 004 (systems analyst) 005 (n.e.c.)	10060201 (business programmer) 10060202 (scientific programmer) 10060401 (business systems analyst) 10060402 (scientific systems analyst)
11. Mathematical specialists	034 (actuary) 035 (mathematician) 036 (statistician)	10060200 (actuary) 10060400 (1&3) (mathematical science) 10060600
12. Agricultural scientists	042	10040200
13. Biological scientists	044	10040600 (life) 10040601 (biological) 10040602 (medical)
14. Chemists	045	10040800
15. Earth scientists	051 (geologist) 052 (marine)	10041000 (geologist) 10041201 (ocean)
16. Physicists/astronomers	053	10041400 (physicist) 10041402 (astronomer)
17. Other life and physical scientists	043 (atmosphere/space) 054 (n.e.c.)	10040400 (meteorological) 10041601 (&5) (natural/ mathematical) 10041602 (physical) 10041603 (other physical) 10041604 (&6) (life) 10041600 (other life and physical)
18. Economists	091	10180201 (financial analyst) 10180200 (&2) (economist) 10180204 (media analyst) 10180205 (market research analyst)
19. Psychologists	093	10180600
20. Sociologists	094	10180800
21. Social scientists, n.e.c.	096 (n.e.c.) 092 (political) 045 (urban/regional)	10181200 (n.e.c.) 10180401 (political science) 10181000 (urban/regional) 10181201 (social science)

new entrant component

New entrants to the S/E labor market are those individuals who terminate their education and enter the work force for the first time to pursue full-time, S/E employment. For most of the relevant occupations, new entrants are the major source of labor supply available to meet growth requirements and replacement needs. Five model subcomponents depict the chain of behavior that culminates in an increment to S/E supply from this source: (1) degree attainment, (2) curriculum choice, (3) participation of foreign nationals in U.S. higher education, (4) labor force entry, and (5) occupational choice.

(1) Degree attainment. Assuming that decisions regarding college degrees are independent of curriculum choice, the initial step in estimating the number of new entrants involves projecting U.S. degree conferrals (baccalaureate through doctorate) over the simulation period. The six sex/degree projection equations are estimated using 1951-80 data from the National Center for Education Statistics (NCES) and relate degree attainment rates to demographic trends and income factors.

(2) Curriculum determination. The next subcomponent projects the number of S/E awarded degrees at each degree level. Availability of job opportunities in various S/E occupations is assumed to be an important determinant of the ultimate choice in curriculum, with relative changes in occupational demand inducing students to switch majors. Degree conferral data were obtained from NCES for the 1968-81 period. Three projection equations, by degree level, were estimated, relating the proportion of degrees conferred in each of 22 curriculums to movements in the share of professional and technical jobs in the most closely aligned S/E occupation. The functional form chosen allows for response differences by curriculum, since the scope of potential job opportunities varies by major.

(3) Foreign nationals in U.S. higher education. In recent years, there has been rapid growth of foreign national participation in technical curriculums, particularly at the graduate level. This subcomponent subtracts foreign nationals from degree recipients by curriculums under the assumption that these students return to their homeland. The proportion of foreign national S/E degree recipients was based on 1978-79 NCES data and detailed enrollment data provided by NSF.

(4) Labor force entry. A substantial number of degree recipients pursue nonmarket activities, including graduate school. This subcomponent filters from available supply all graduates who do not enter the full-time labor force. Labor force entry rates are primarily determined by degree and field of major and remain fairly stable over time. The model projects future labor force participation based on the behavior of 1972-79 graduating classes as derived from NSF Surveys of Recent Science and Engineering Graduates Degree conferrals at the bachelor's- and master's-degree levels are adjusted downward, across curriculums, to reflect varying labor market entry behavior all doctoral candidates are assumed to enter the work force.

(5) Occupational choice. This subcomponent allocates labor force participants from various majors to occupations. For each major, the probability of entering a given occupation is modeled as a function of: (a) labor market conditions in the destination occupation, (b) the similarity of college coursework across various majors and occupations, and (c) qualitative attributes which affect propensities of graduates in broad fields of study (engineering, computer sciences and mathematics, life and physical sciences, and social sciences) to enter the occupation nominally associated with their major. Projection equations for bachelor's- and master's- degree recipients are based on 1976-79 NSF Surveys of Recent Science and Engineering Graduates. Doctorates are assumed to enter that occupation most closely associated with their field of study.

experienced worker component

Experienced workers play an important role in determining the ability of supply to adjust to short-run changes in demand. Two model subcomponents describe the major types of experienced worker behavior—occupational mobility and attrition. To date, mobility patterns of experienced workers have seldom been incorporated into supply projections because of the lack of theoretical research and the scarcity of data.

(1) Occupational mobility. This model subcomponent estimates net changes in S/E occupational supply which result from movements of workers into and out of S/E occupations and between the S/E occupations themselves.[7] Mobility rates are estimated across 25 professional and technical, as well as managerial occupations, 13 major S/E categories were among these.[8] Mobility rates are modeled as a function of: (a) the proportion of individuals remaining in an occupation from the previous time period (a proxy for labor market demand), (b) the proportion of employment represented by new entrants, (c) occupational characteristics (percent of women and the average educational level in a given occupation) believed to determine the share of supply generated by reentrants to the work force, and (d) qualitative variables measuring behavioral differences across occupations.

Two versions of this subcomponent were estimated. The gross mobility version estimated rates of inmobility to an occupation in the manner described in the preceding paragraph. In the net mobility version, net (inflow minus outflow) mobility rates were similiarly estimated. The difference between the two model versions rests in the handling of occupational outmobility. The gross mobility version assumes out-mobility rates from an occupation are dependent solely on age, education, and sex, the net mobility version assumes these rates are sensitive to relative demand/supply conditions.

The mobility subcomponent uses two data bases: The Current Population Survey (CPS) conducted in January 1973, 1978, and 1981, and NSF Surveys of Experienced Scientists and Engineers conducted during the seventies.

(2) Attrition. The available supply of S/E personnel is reduced by deaths and retirements. Projected attrition through deaths is based on constant, sex-specific death rates which were reported by the BLS for the general population in 1970. Projected attrition through retirements of S/E personnel is modeled as a function of age and educational level of that population over 50 years of age; 1972-78 data from NSF Surveys of Experienced Scientists and Engineers were used for estimation

immigration component

Immigrant scientists and engineers are an important source of S/E labor supply. This component provides projections of the number of immigrants by S/E occupation. The estimation equation is based on 1962-79 data and relates the number of S/E immigrants in a specific occupation to variables reflecting: (1) job opportunities in the occupation of employment, (2) changes in immigration laws, and (3) differences in occupation-specific immigration behavior.

[7] An alternative gross-mobility specification was also estimated which parallels the earlier modeling effort Under this specification, out-mobility rates were not responsive to labor market conditions, but were instead determined by the age, education, and sex characteristics of various occupations The net-mobility specification was considered preferable because exit rates from an occupation are believed to be dependent on occupational opportunities throughout the labor force Both the gross- and net-mobility specifications are reported and analyzed in Robert C. DauffenBach and Jack Fiorito, *Projections of Supply of Scientists and Engineers to Meet Defense and Nondefense Requirements, 1981-87*, ibid.

[8] Small samples sizes in S/E occupations precluded greater disaggregation in these fields

appendix b

detailed statistical tables

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Table B-1. Summary table of U.S. economy: 1982-87—STAG/LOW

Macroeconomic indicators	1982	1983	1984	1985	1986	1987
	Gross national product (GNP) [In billions]					
GNP	$3,064.9	$3,302.6	$3,596.8	$3,947.5	$4,303.4	$4,662.6
Real GNP, 1972 dollars	1,485.5	1,499.2	1,517.8	1,546.3	1,578.1	1,611.1
Annual rate of change	-1.6	.9	1.2	1.9	2.1	2.1
	Defense expenditures [In billions]					
Purchases	$178.1	$201.8	$226.7	$253.4	$280.3	$308.0
Real purchases, 1972 dollars	78.2	81.7	84.1	86.7	89.3	91.9
Annual rate of change	5.8	4.5	3.0	3.0	3.0	3.0
Prime contracts	127.8	139.1	158.9	175.1	192.1	209.5
Price deflator, annual rate of change	9.2	8.5	9.0	8.6	7.4	6.7
	Prices, wages, productivity—annual rates of change [Percent]					
GNP deflator	6.5	6.8	7.6	7.7	6.8	6.1
Consumer price index	6.2	7.2	7.8	7.8	7.1	6.3
Compensation per hour	7.2	7.4	8.2	9.2	8.8	8.0
Output per hour	-.4	1.3	.5	2.0	.7	.9
	Labor force [In millions]					
Military personnel	2.1	2.2	2.2	2.1	2.1	2.1
Civilian labor force	110.2	112.4	114.4	115.9	117.5	119.1
Employment	100.0	102.0	103.5	103.6	104.2	105.2
Unemployment rate	9.2	9.3	9.6	10.6	11.3	11.7
	Industrial production					
Industrial production index (1967=1.0)	1.399	1.420	1.446	1.493	1.530	1.561
Annual rate of change	-7.3	1.5	1.9	3.2	2.4	2.1
Manufacturing industries: Production, annual rate of change	-7.8	1.7	1.9	3.5	2.7	2.3
Capacity utilization rate	71.3	72.0	72.0	71.2	72.5	73.4

NOTES. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. Projection scenarios were derived using the Defense Interindustry Forecasting System developed by Data Resources, Incorporated (DRI)

SOURCE: National Science Foundation

Table B-2. Summary table of U.S. economy: 1982-87—STAG/HIGH

Macroeconomic indicators	1982	1983	1984	1985	1986	1987
	Gross national product (GNP) [In billions]					
GNP	$3,066.3	$3,325.9	$3,655.2	$4,403.1	$4,429.4	$4,822.5
Real GNP, 1972 dollars	1,486.1	1,508.6	1,539.5	1,575.1	1,614.3	1,654.6
Annual rate of change	-1.6	1.5	2.0	2.3	2.5	2.5
	Defense expenditures [In billions]					
Purchases	$179.4	$216.2	$256.1	$303.7	$349.5	$389.9
Real purchases, 1972 dollars	78.8	87.4	95.0	103.6	111.0	116.1
Annual rate of change	6.6	11.0	8.6	9.1	7.1	4.6
Prime contracts	128.2	145.9	174.9	203.6	233.1	259.8
Price deflator, annual rate of change	9.2	8.5	9.1	8.7	7.5	6.7
	Prices, wages, productivity—annual rates of change [Percent]					
GNP deflator	6.5	6.8	7.7	8.1	6.9	6.2
Consumer price index	6.2	7.3	7.9	8.4	6.9	6.3
Compensation per hour	7.2	7.5	8.4	9.3	9.0	8.3
Output per hour	-.4	1.4	.6	1.6	1.3	.9
	Labor force [In millions]					
Military personnel	2.1	2.2	2.2	2.2	2.3	2.3
Civilian labor force	110.2	112.4	114.4	115.9	117.5	119.1
Employment	100.0	102.2	104.0	104.4	105.3	106.5
Unemployment rate	9.2	9.1	9.1	9.9	10.4	10.6
	Industrial production					
Industrial production index (1967=1.0)	1.399	1.432	1.478	1.539	1.579	1.620
Annual rate of change	-7.3	2.4	3.2	4.1	2.6	2.6
Manufacturing industries:						
Production, annual rate of change	-7.8	2.8	3.4	4.3	3.0	2.8
Capacity utilization rate	71.3	72.7	73.7	73.3	74.8	76.2

NOTES: STAG/HIGH indicates low-economic growth/high-defense expenditure scenario. Projection scenarios were derived using the Defense Interindustry Forecasting System developed by Data Resources, Incorporated (DRI)

SOURCE: National Science Foundation

Table B-3. Summary table of U.S. economy: 1982-87—OPTIM/LOW

Macroeconomic indicators	1982	1983	1984	1985	1986	1987
	Gross national product (GNP) (In billions)					
GNP	$3,072.7	$3,379.8	$3,710.4	$4,085.1	$4,466.1	$4,865.9
Real GNP, 1972 dollars	1,490.5	1,552.9	1,619.9	1,681.6	1,724.8	1,769.3
Annual rate of change	-1.3	4.2	4.3	3.8	2.8	2.6
	Defense expenditures (In billions)					
Purchases	$179.5	$199.7	$220.2	$243.6	$269.0	$295.9
Real purchases, 1972 dollars	78.9	81.7	84.1	86.7	89.3	91.9
Annual rate of change	6.7	3.6	3.0	3.0	3.0	3.0
Prime contracts	128.8	138.3	155.8	169.5	185.1	201.9
Price deflator, annual rate of change	9.1	7.4	7.1	7.5	7.1	8.8
	Prices, wages, productivity—annual rates of change (Percent)					
GNP deflator	6.4	5.6	5.2	6.1	6.8	6.2
Consumer price index	6.1	5.3	5.0	6.8	6.9	6.5
Compensation per hour	7.0	6.0	6.4	6.1	6.3	6.1
Output per hour	-.2	3.4	2.5	.0	1.6	1.4
	Labor force (In millions)					
Military personnel	2.1	2.2	2.2	2.1	2.1	2.1
Civilian labor force	110.1	112.4	114.7	116.4	118.1	119.7
Employment	100.1	103.2	106.5	108.1	109.8	111.1
Unemployment rate	9.2	8.2	7.1	7.1	7.1	7.2
	Industrial production					
Industrial production index (1967 = 1.0)	1.407	1.517	1.632	1.716	1.767	1.815
Annual rate of change	-6.6	7.9	7.6	5.2	3.0	2.7
Manufacturing industries:						
Production, annual rate of change	-7.2	8.6	8.1	5.5	3.2	3.0
Capacity utilization rate	71.5	76.3	79.4	79.0	79.2	79.1

NOTES. OPTIM/LOW indicates high-economic growth/low-defense expenditure scenario. Projection scenarios were derived using the Defense Interindustry Forecasting System developed by Data Resources, Incorporated (DRI).

SOURCE: National Science Foundation

Table B-4. Summary table of U.S. economy: 1982-87—OPTIM/HIGH

Macroeconomic Indicators	1982	1983	1984	1985	1986	1987
	Gross national product (GNP) [In billions]					
GNP	$3,071.6	$3,402.2	$3,768.3	$4,167.6	$4,635.3	$5,116.1
Real GNP, 1972 dollars	1,489.9	1,561.9	1,641.6	1,722.2	1,777.4	1,835.2
Annual rate of change	-1.4	4.8	5.1	4.9	3.2	3.3
	Defense expenditures [In billions]					
Purchases	$179.3	$213.9	$248.9	$291.9	$335.3	$376.1
Real purchases, 1972 dollars	78.8	87.4	95.0	103.6	111.0	116.1
Annual rate of change	6.6	11.0	8.6	9.1	7.1	4.6
Prime contracts	128.2	144.9	171.2	196.8	224.4	250.9
Price deflator, annual rate of change	9.1	7.5	7.1	7.5	7.3	7.2
	Prices, wages, productivity—annual rate of change [Percent]					
GNP deflator	6.4	5.6	5.4	5.4	7.8	6.9
Consumer price index	6.0	5.4	5.1	3.8	10.4	7.2
Compensation per hour	7.0	6.1	6.6	8.2	8.6	9.0
Output per hour	-.2	3.5	2.7	.4	2.0	1.6
	Labor force [In millions]					
Military personnel	2.1	2.2	2.2	2.2	2.3	2.3
Civilian labor force	110.2	112.4	114.7	116.4	118.2	119.8
Employment	100.0	103.4	107.0	109.1	111.0	112.7
Unemployment rate	9.2	8.1	6.7	6.3	6.1	5.9
	Industrial production					
Industrial production index (1967 = 1.0)	1.405	1.530	1.668	1.790	1.861	1.934
Annual rate of change	-6.9	8.9	9.0	7.3	4.1	3.7
Manufacturing industries:						
Production, annual rate of change	-7.3	10.1	9.7	7.5	4.8	4.0
Capacity utilization rate	71.4	77.0	81.2	82.2	83.3	83.8

NOTES: OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Projection scenarios were derived using the Defense Interindustry Forecasting System developed by Data Resources, Incorporated (DRI).

SOURCE: National Science Foundation.

Table B-5. Projected growth in defense and nondefense requirements of scientists, engineers, and technicians: 1982-87—STAG/LOW

[In thousands]

Occupation	Total requirements 1982	Total requirements 1987	Total requirements Annual growth rate	Defense requirements 1982	Defense requirements 1987	Defense requirements Annual growth rate	Nondefense requirements 1982	Nondefense requirements 1987	Nondefense requirements Annual growth rate
Total scientists	726.6	843.2	3.0%	21.9	29.4	6.1%	704.7	813.5	2.9%
Computer systems analysts	219.1	287.3	5.6	10.0	15.3	8.9	209.1	271.9	5.4
Life:									
Agricultural	17.2	17.3	.1	.1	.1	.0	17.0	17.2	.2
Biologists	55.3	59.4	1.4	.7	.8	2.7	54.7	58.7	1.4
Physical:									
Chemists	90.7	97.7	1.5	2.8	3.4	4.0	87.9	94.3	1.4
Geologists	42.7	47.9	2.3	1.1	1.3	3.4	41.7	46.6	2.2
Physicists	20.9	22.4	1.4	1.1	1.3	3.4	19.8	21.0	1.2
Life/physical, n.e.c.	27.6	29.5	1.3	.7	.9	5.1	26.8	28.6	1.3
Mathematical	51.0	56.9	2.2	2.4	2.6	3.1	48.6	54.0	2.1
Social	202.1	224.6	2.2	3.0	3.5	3.1	199.1	221.2	2.1
Economists	30.3	34.6	2.8	.8	1.0	4.6	29.5	33.7	2.7
Psychologists	90.4	100.5	2.1	1.0	1.0	.0	89.4	99.4	2.1
Sociologists	9.3	10.1	1.7	.1	.1	.0	9.2	10.0	1.7
Social, n.e.c.	72.1	79.4	1.9	1.1	1.4	4.9	71.0	78.1	1.9
Total engineers	1,136.8	1,296.4	2.6	136.6	187.0	6.1	1,000.0	1,109.3	2.1
Aeronautical/astronautical	64.2	85.5	5.9	33.5	50.4	8.5	30.7	35.1	2.7
Chemical	53.1	57.4	1.6	2.6	3.1	3.6	50.6	54.3	1.4
Civil	163.4	174.7	1.3	3.4	4.0	3.3	160.0	170.7	1.3
Electrical/electronic	327.1	396.3	3.9	41.2	56.1	6.4	285.9	340.2	3.5
Industrial	109.2	120.3	2.0	9.7	12.4	5.0	99.5	107.9	1.6
Mechanical	202.0	223.9	2.1	18.9	24.6	5.4	183.1	199.3	1.7
Metallurgical	14.6	16.3	1.9	1.4	1.9	6.3	13.3	14.4	1.6
Mining/petroleum	27.6	31.7	2.6	.9	1.1	4.1	26.7	30.6	2.6
Engineers, n.e.c.	177.4	190.3	1.4	27.2	33.4	4.2	150.2	156.6	.9
Total technicians	1,465.5	1,648.9	2.4	83.6	106.5	5.0	1,382.0	1,542.2	2.2
Computer programmers	235.0	290.3	4.3	9.6	12.9	6.1	225.4	277.3	4.2
Drafters	312.0	336.5	1.6	17.1	20.7	3.9	294.9	317.6	1.5
Electrical/electronic engineering	345.3	399.9	3.0	28.6	37.8	5.7	316.7	362.0	2.7
Industrial engineering	30.5	33.4	1.6	2.3	2.8	4.0	28.2	30.6	1.6
Mechanical engineering	44.7	50.5	2.5	8.3	10.7	5.2	36.4	39.8	1.8
Science/engineering, n.e.c.	498.0	536.3	1.5	17.7	21.6	4.1	480.4	514.7	1.4

NOTES. STAG/LOW indicates low-economic growth/high-defense expenditure scenario. Because of rounding, components may not add to totals.

SOURCE: National Science Foundation

Table B-6. Projected growth in defense and nondefense requirements of scientists, engineers, and technicians: 1982-87—STAG/HIGH

[In thousands]

Occupation	Total requirements 1982	Total requirements 1987	Total requirements Annual growth rate	Defense requirements 1982	Defense requirements 1987	Defense requirements Annual growth rate	Nondefense requirements 1982	Nondefense requirements 1987	Nondefense requirements Annual growth rate
Total scientists	726.9	862.1	3.5	%22.0	33.2	6.6	%704.9	828.6	3.2%
Computer systems analysts	219.3	294.7	6.1	10.0	17.6	12.0	209.1	277.0	5.8
Life:									
Agricultural	17.2	17.5	.3	.1	.1	.0	17.0	17.4	.5
Biologists	55.3	60.4	1.6	.7	.8	2.7	54.7	59.5	1.7
Physical:									
Chemists	90.7	99.6	1.9	2.9	3.7	5.0	67.9	95.9	1.6
Geologists	42.7	46.2	2.4	1.1	1.3	3.4	41.7	46.9	2.4
Physicists	20.9	23.4	2.3	1.1	1.6	7.9	19.6	21.8	1.9
Life/physical, n.e.c.	27.6	30.4	2.0	.7	1.0	7.4	26.9	29.4	1.8
Mathematical	51.0	58.7	2.8	2.4	3.3	6.6	48.6	55.4	2.6
Social	202.2	229.2	2.5	3.0	3.8	4.8	199.2	225.3	2.5
Economists	30.3	35.3	3.1	.6	1.2	8.4	29.5	34.1	2.9
Psychologists	90.4	101.7	2.4	1.0	1.0	.0	89.4	100.6	2.4
Sociologists	9.3	10.3	2.1	.1	.1	.0	9.2	10.2	2.1
Social, n.e.c.	72.2	81.9	2.6	1.1	1.5	6.4	71.1	80.4	2.5
Total engineers	[illegible]40.3	1,373.2	3.8	139.2	223.6	9.9	1,001.0	1,149.7	2.8
Aeronautical/astronautical	64.5	107.2	10.7	33.7	64.8	14.0	30.8	42.4	6.6
Chemical	53.1	58.7	2.0	2.6	3.4	5.5	50.6	55.4	1.8
Civil	163.5	179.1	1.8	3.4	4.3	4.6	160.1	174.9	1.8
Electrical/electronic	327.6	415.2	4.8	41.3	63.7	9.0	286.2	351.4	4.2
Industrial	109.3	125.0	2.7	9.7	14.5	8.4	99.6	110.5	2.1
Mechanical	202.2	233.4	2.9	18.9	28.8	8.8	183.2	204.6	2.2
Metallurgical	14.8	17.1	2.9	1.4	2.2	9.5	13.4	14.9	2.1
Mining/petroleum	27.6	31.6	2.9	.9	1.1	4.0	26.7	30.7	2.8
Engineers, n.e.c.	177.7	205.7	3.0	27.3	40.8	6.4	150.4	164.9	1.6
Total technicians	1,466.4	1,694.2	2.9	83.9	120.4	7.5	1,382.5	1,573.9	2.6
Computer programmers	235.1	294.4	4.6	9.6	14.2	6.1	225.5	280.2	4.4
Drafters	312.2	347.5	2.2	17.2	22.6	5.6	295.0	324.8	1.9
Electrical/electronic engineering	345.5	410.2	3.5	28.7	42.7	8.3	316.8	367.6	3.0
Industrial engineering	30.5	34.6	2.6	2.3	3.2	6.8	28.2	31.4	2.2
Mechanical engineering	44.8	54.6	4.0	6.4	13.0	9.1	36.4	41.6	2.7
Science/engineering, n.e.c.	496.3	552.9	2.1	17.7	24.7	6.9	480.6	528.3	1.9

NOTES. STAG/HIGH indicates low-economic growth/high-defense expenditure scenario. Because of rounding, components may not add to totals.

SOURCE: National Science Foundation

Table B-7. Projected growth in defense and nondefense requirements of scientists, engineers, and technicians: 1982-87—OPTIM/LOW

[In thousands]

Occupation	Total requirements 1982	Total requirements 1987	Total requirements Annual growth rate	Defense requirements 1982	Defense requirements 1987	Defense requirements Annual growth rate	Nondefense requirements 1982	Nondefense requirements 1987	Nondefense requirements Annual growth rate
Total scientists	727.3	865.6	3.5%	22.0	30.3	6.8%	705.5	835.5	3.4%
Computer systems analysts	219.3	294.7	6.1	10.0	15.6	9.3	209.3	279.0	5.9
Life:									
Agricultural	17.2	18.1	1.0	.1	.2	14.9	17.1	18.0	1.0
Biologists	55.3	61.4	2.1	.7	.6	2.7	54.6	60.7	2.1
Physical:									
Chemists	90.9	100.3	2.0	2.9	3.5	3.8	88.1	96.6	1.9
Geologists	42.8	47.3	2.0	1.1	1.2	1.8	41.7	46.1	2.0
Physicists	20.9	23.1	2.0	1.1	1.4	4.9	19.9	21.8	1.8
Life/physical, n.e.c.	27.6	30.3	1.9	.7	.9	5.1	26.9	29.4	1.8
Mathematical	51.0	58.1	2.8	2.4	3.0	4.6	48.6	55.1	2.5
Social	202.3	232.3	2.8	3.0	3.7	4.3	199.3	226.6	2.8
Economists	30.3	35.5	3.2	.8	1.1	6.6	29.5	34.4	3.1
Psychologists	90.5	105.0	3.0	1.0	1.1	1.9	89.5	103.9	3.0
Sociologists	9.3	10.5	2.4	.1	.1	.0	9.2	10.4	2.5
Social, n.e.c.	72.2	81.3	2.4	1.1	1.4	4.9	71.1	79.9	2.4
Total engineers	1,142.0	1,337.0	3.2	139.2	190.5	8.5	1,002.6	1,148.6	2.7
Aeronautical/astronautical	64.5	88.0	6.4	33.6	51.3	8.8	30.8	36.7	3.6
Chemical	53.2	59.2	2.2	2.6	3.2	4.2	50.7	56.0	2.0
Civil	163.7	183.8	2.3	3.4	4.2	4.3	160.3	179.6	2.3
Electrical/electronic	327.8	399.6	4.0	41.3	56.1	6.3	286.5	343.5	3.7
Industrial	109.5	124.6	2.6	9.7	12.8	5.7	99.8	111.8	2.3
Mechanical	202.7	235.7	3.1	16.9	25.6	6.2	183.7	210.2	2.7
Metallurgical	14.9	17.4	3.2	1.5	2.0	5.9	13.4	15.4	2.8
Mining/petroleum	27.7	31.2	2.4	.9	1.1	4.1	26.7	30.1	2.4
Engineers, n.e.c.	178.0	197.5	2.1	27.3	34.2	4.6	150.7	163.3	1.6
Total technicians	1,468.3	1,703.0	3.0	83.9	109.5	5.5	1,384.4	1,593.7	2.8
Computer programmers	235.2	294.8	4.6	9.8	13.2	6.6	225.6	281.7	4.5
Drafters	312.9	355.8	2.6	17.2	21.6	4.7	295.7	334.2	2.5
Electrical/electronic engineering	345.6	408.1	3.4	28.7	36.1	5.8	316.9	370.0	3.1
Industrial engineering	30.6	34.9	2.7	2.3	3.0	5.4	28.3	32.0	2.5
Mechanical engineering	44.9	52.8	3.2	8.4	11.2	5.9	36.5	41.4	2.6
Science/engineering, n.e.c.	499.1	556.6	2.2	17.7	22.4	4.8	481.4	534.4	2.1

NOTES. OPTIM/LOW indicates high-economic growth/low-defense expenditure scenario. Because of rounding, components may not add to totals.

SOURCE: National Science Foundation

Table B-8. Projected growth in defense and nondefense requirements of scientists, engineers, and technicians: 1982-87—OPTIM/HIGH

[In thousands]

Occupation	Total requirements 1982	Total requirements 1987	Total requirements Annual growth rate	Defense requirements 1982	Defense requirements 1987	Defense requirements Annual growth rate	Nondefense requirements 1982	Nondefense requirements 1987	Nondefense requirements Annual growth rate
Total scientists	727.4	888.0	4.1%	22.0	34.2	9.2%	705.5	854.2	3.9%
Computer systems analysts	219.3	303.3	6.7	10.0	17.9	12.3	209.2	285.5	6.4
Life:									
Agricultural	17.2	18.4	1.4	.1	.2	14.9	17[illegible]	18.2	1.2
Biologists	55.4	62.5	2.4	.7	.8	2.7	54.7	61.7	2.4
Physical:									
Chemists	90.9	102.6	2.5	2.9	3.8	5.5	88.0	99.0	2.4
Geologists	42.8	47.9	2.3	1.1	1.3	3.4	41.7	46.6	2.2
Physicists	20.9	24.2	3.0	1.1	1.6	7.9	19.9	22.6	2.6
Life/physical, n.e.c.	27.6	31.3	2.5	.7	1.1	9.5	26.9	30.3	2.4
Mathematical	51.0	60.6	3.5	2.4	3.5	7.8	48.7	57.2	3.3
Social	202.3	237.0	3.2	3.0	4.0	5.9	199.3	233.1	3.2
Economists	30.3	36.2	3.6	.6	1.3	10.2	29.5	35.0	3.5
Psychologists	90.5	106.2	3.2	1.0	1.1	1.9	89.5	105.1	3.3
Sociologists	9.3	10.7	2.8	.1	.1	.0	9.2	10.6	2.9
Social, n.e.c.	72.2	83.9	3.0	1.1	1.5	6.4	71.1	82.4	3.0
Total engineers	1,142.1	1,423.1	4.5	139.5	226.4	10.2	1,002.2	1,196.8	3.6
Aeronautical/astronautical	64.5	109.2	11.1	33.7	65.2	14.1	30.9	44.0	7.3
Chemical	53.2	60.9	2.7	2.6	3.5	6.1	50.7	57.5	2.5
Civil	163.7	188.9	2.9	3.4	4.4	5.3	160.3	184.5	2.8
Electrical/electronic	327.9	420.6	5.1	41.4	63.6	9.0	286.5	357.0	4.5
Industrial	109.5	130.8	3.6	9.7	14.9	9.0	99.8	115.9	3.0
Mechanical	202.7	248.2	4.1	19.0	29.9	9.5	183.7	218.3	3.5
Metallurgical	14.9	18.5	4.4	1.5	2.4	9.9	13.4	16.2	3.9
Mining/petroleum	27.7	31.6	2.7	.9	1.1	4.1	26.7	30.4	2.6
Engineers, n.e.c.	178.0	214.4	3.8	27.3	41.4	8.7	150.7	173.0	2.8
Total technicians	1,468.3	1,760.4	3.7	83.9	123.5	8.0	1,384.4	1,636.9	3.4
Computer programmers	235.2	300.5	5.0	9.6	14.4	8.4	225.6	286.0	4.8
Drafters	312.9	368.5	3.3	1.2	23.7	6.6	295.6	344.8	3.1
Electrical/electronic engineering	345.6	421.0	4.0	26.7	42.9	6.4	317.0	378.1	3.6
Industrial	30.6	36.6	3.6	2.3	3.4	8.1	28.3	33.2	3.2
Mechanical engineering	44.9	57.3	5.0	6.4	13.6	10.1	38.5	43.7	3.7
Science/engineering, n.e.c.	499.1	576.5	2.9	17.7	25.5	7.6	481.4	551.1	2.7

NOTES OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Because of rounding, components may not add to totals.

SOURCE National Science Foundation

Table B-9. Supply/demand balance of scientists and engineers based on new entrants and immigrants supply model: 1981 and 1987—STAG/LOW

[In thousands]

Occupation	1981 Total supply	1981 Supply components: New entrants	1981 Supply components: Attrition	1981 Supply components: Immigration	1981 Demand	1981 Balance surplus (+)/shortage (-)	1981 Balance as percent of supply	1987 Total supply	1987 Supply components: New entrants	1987 Supply components: Attrition	1987 Immigration	1987 Demand	1987 Balance surplus (+)/shortage (-)	1987 Balance as percent of supply
Total scientists	573.0	85.0	9.8	2.3	508.3	64.7	11.3	1,040.0	91.5	30.1	3.0	555.9	484.1	46.5
Agricultural	25.0	5.3	.4	.2	17.6	7.4	29.6	52.8	4.8	1.0	.2	17.3	35.5	67.2
Biologists	71 1	19.0	1.0	.2	55.4	15.7	22.1	176.0	19.6	3.2	.3	59.4	116.6	66.3
Chemists	98.6	6.0	1.9	.8	93.7	4.9	5.0	126.9	6.4	2.5	1.0	97.7	31.2	24.2
Geologists	43.2	4.1	.6	.1	40.6	2.6	6.0	66.1	4.8	1.2	.2	47.9	18.2	27.5
Mathematical	56.9	5.8	1.0	.1	51.8	5.1	9.0	84.9	5.8	1.6	.2	56.9	28.0	33.0
Physicists	23.1	2.8	.4	.2	21.1	2.0	8.6	38.7	3.0	.7	.2	22.4	16.3	42 1
Other life and physical	28.6	1.9	.5	.1	28.2	.4	1.4	37.3	2.0	.7	.1	29.5	7.8	20.9
Social	226.5	40.1	3.8	.6	199.9	26.6	11.7	455.3	45 1	19.2	.8	224.8	230.5	50.6
Economists	49.6	7.1	.9	.3	30.2	19.4	39.1	93.3	8.1	1.7	.3	34.8	58.5	62.7
Psychologists	93.5	12.5	1.6	.2	68.3	5.2	5.6	162.9	14.5	3.0	.3	100.5	62.4	36.3
Sociologists	11.9	5.6	.1	.0	9.2	2.7	22.7	50.9	7.2	.9	.0	10.1	40.8	80.2
Social, n.e.c.	71.5	14.9	1.2	.1	72.2	-.7	-.1	148.2	15.3	2.7	.2	79.4	68.8	46.4
Total engineers	1,223.7	63.5	23.5	6.2	1,155.6	68.1	5.6	1,494.8	64.8	29.1	6.8	1,296.4	198.4	13.3
Aeronautical/astronautical	68.6	1.9	1.4	.1	63.2	5.4	7.9	72.8	2.1	1.4	.2	85.5	-12.7	-17.4
Chemical	60.5	5.6	1.1	.5	55.1	5.4	8.9	87.7	5.3	1.7	.5	57.4	30.3	34.6
Civil	173.0	10.2	3.3	.7	165.5	7.5	4.3	218.2	10.0	4.2	.8	174.7	41.5	19.2
Electrical/electronic	334.6	13.6	6.5	.9	324.4	10.2	3.0	387.2	1.3	7.6	1.2	396.3	-9.1	-2.4
Industrial	117.8	4.0	2.3	.2	113.3	4.5	3.8	129.3	4.0	2.6	.3	120.3	9.0	7.0
Mechanical	220.9	11.4	4.2	.9	208.5	12.4	5.6	267.3	11.4	5.2	1.0	223.9	43.4	16.2
Metallurgical	16.6	1.4	.3	.1	15.6	1.0	6.0	23.1	1.3	.4	.1	16.3	6.8	29.4
Mining/petroleum	25.6	2.0	.5	.1	26.1	-.5	-2.0	35.9	2.2	.7	.1	31.7	4.2	11.7
Engineers, n.e.c.	206.1	13.4	3.9	2.7	183.9	22.2	10.8	275.3	13.2	5.3	2.6	190.3	85.0	31.0
Computer specialists[1]	435.9	9.9	8.6	.8	442.9	-8.0	-1.6	462.3	13.6	9.1	1.2	577.6	-115.3	-25.0

[1]Includes both computer systems analysts and computer programmers.

NOTES. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-10. Supply/demand balance of scientists and engineers based on new entrants and immigrants supply model: 1981 and 1987—STAG/HIGH

[In thousands]

Occupation	1981							1987						
	Total supply	Supply components			Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply	Total supply	Supply components			Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply
		New entrants	Attrition	Immigration					New entrants	Attrition	Immigration			
Total scientists	573.0	85.0	9.8	2.3	508.3	64.7	11.3	1,042.5	92.7	19.2	3.0	567.4	475.1	46.0
Agricultural	25.0	5.3	.4	.2	17.6	7.4	29.6	52.9	4.9	1.0	.2	17.5	35.4	66.9
Biologists	71.1	19.0	1.0	.2	55.4	15.7	22.1	176.3	19.8	3.2	.3	60.4	115.9	65.7
Chemists	98.6	6.0	1.9	.8	93.7	4.9	5.0	129.1	6.4	2.5	1.0	99.6	29.5	22.8
Geologists	43.2	4.1	.8	.1	40.6	2.6	6.0	66.2	4.9	1.2	.2	48.2	18.0	27.2
Mathematical	56.9	5.8	1.0	.1	51.6	5.1	9.0	85.1	5.9	1.6	.2	58.7	26.4	31.0
Physicists	23.1	2.8	.4	.2	21.1	2.0	8.6	38.8	3.1	.7	.2	23.4	15.4	39.7
Other life and physical	28.6	1.9	.5	.1	28.2	.4	1.4	37.3	2.0	.7	.1	30.4	6.9	18.5
Social	226.5	40.1	3.8	.6	199.9	26.6	11.7	456.8	45.7	8.3	.8	229.2	227.6	49.8
Economists	49.6	7.1	.9	.3	30.2	19.4	39.1	93.5	8.2	1.7	.3	35.3	58.2	62.2
Psychologists	93.5	12.5	1.6	.2	88.3	5.2	5.6	163.2	14.6	3.0	.3	101.7	61.5	37.7
Sociologists	11.9	5.6	.1	.0	9.2	2.7	22.7	51.0	7.3	.9	.0	10.3	40.7	79.8
Social, n.e.c.	71.5	14.9	1.2	.1	72.2	-.7	-.1	149.1	15.6	2.7	.2	81.9	67.2	45.1
Total engineers	1,223.7	63.5	23.5	6.2	1,155.6	68.1	5.6	1,502.0	67.4	29.1	6.9	1,373.2	128.8	8.6
Aeronautical/ astronautical	68.6	1.9	1.4	.1	63.2	5.4	7.9	73.9	2.4	1.4	.2	107.2	-33.3	-45.1
Chemical	60.5	5.6	1.1	.5	55.1	5.4	8.9	87.8	5.4	1.7	.5	58.7	29.1	33.1
Civil	173.0	10.2	3.3	.7	165.5	7.5	4.3	216.5	10.1	4.2	.8	179.1	37.4	17.3
Electrical/ electronic	334.6	13.6	6.5	.9	324.4	10.2	3.0	389.2	15.9	7.6	1.3	415.2	-26.0	-6.7
Industrial	117.8	4.0	2.3	.2	113.3	4.5	3.8	129.6	4.1	2.6	.3	125.0	4.6	3.5
Mechanical	220.9	11.4	4.2	.9	208.5	12.4	5.6	268.4	11.8	5.2	1.0	233.4	35.0	13.0
Metallurgical	16.6	1.4	.3	.1	15.6	1.0	6.0	23.1	1.4	.4	.1	17.1	6.0	26.0
Mining/ petroleum	25.6	2.0	.5	.9	26.1	-.5	-2.0	35.9	2.3	.7	.1	31.8	4.1	11.4
Engineers, n.e.c.	206.1	13.4	3.9	2.7	183.9	22.2	10.8	277.6	14.0	5.3	2.6	205.7	71.9	25.9
Computer specialists[1]	434.9	9.9	8.6	.8	442.9	-8.0	-1.8	463.7	14.0	9.2	1.3	588.9	-125.2	-27.0

[1] Includes both computer systems analysts and computer programmers.

NOTES: STAG/HIGH indicates low-economic growth/high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-11. Supply/demand balance of scientists and engineers based on new entrants and immigrants supply model: 1981 and 1987—OPTIM/LOW

[In thousands]

Occupation	1981 Total supply	1981 Supply components: New entrants	1981 Supply components: Attrition	1981 Supply components: Immigration	1981 Demand	1981 Balance surplus (+)/ shortage (-)	1981 Balance as percent of supply	1987 Total supply	1987 Supply components: New entrants	1987 Supply components: Attrition	1987 Supply components: Immigration	1987 Demand	1987 Balance surplus (+)/ shortage (-)	1987 Balance as percent of supply
Total scientists	575.0	66.0	10.3	2.2	509.5	65.5	11.4	1,040.9	93.6	20.2	2.9	571.9	469.0	45.17
Agricultural	25.0	5.3	.3	.2	16.0	7.0	28.0	53.0	5.0	1.0	.2	16.1	34.9	65.6
Biologists	71.1	19.0	1.1	.2	55.4	15.7	22.1	176.0	20.0	3.2	.3	71.4	114.6	65.1
Chemists	99.0	6.0	2.0	.6	94.0	5.0	5.1	129.0	6.5	2.5	1.0	100.3	26.7	22.2
Geologists	43.3	4.1	.6	.1	41.0	2.3	5.3	66.0	5.0	1.2	.2	47.3	16.7	26.3
Mathematical	57.0	1.0	1.0	.1	52.0	5.0	8.8	65.0	6.0	2.0	.2	56.1	26.9	31.6
Physicists	23.1	3.0	.4	.2	21.1	2.0	8.7	39.0	3.1	.7	.2	23.1	15.9	40.6
Other life and physical	29.0	2.0	.5	.0	26.2	.6	2.6	37.3	2.0	.7	.0	30.3	7.0	16.6
Social	227.5	40.6	4.2	.6	199.9	27.6	12.1	455.6	46.2	6.9	.6	233.3	222.3	46.6
Economists	50.0	7.1	.9	.3	30.2	19.6	39.6	93.1	6.2	2.0	.3	36.0	57.1	61.3
Psychologists	93.5	12.5	2.0	.2	88.3	5.2	5.6	163.3	15.0	3.0	3.0	105.0	56.3	35.7
Sociologists	12.0	6.0	.1	.0	9.2	2.6	23.3	51.0	7.5	.9	.0	11.0	40.0	76.4
Social, n.e.c.	72.0	15.0	1.2	.1	72.2	.2	.3	146.2	15.5	3.0	.2	61.3	66.9	45.1
Total engineers	1,225.6	64.4	24.2	6.2	1,162.0	62.6	5.1	1,497.6	67.0	27.9	7.3	1,336.2	159.6	10.7
Aeronautical/ astronautical	69.0	2.0	1.4	.0	63.2	5.6	8.4	73.0	2.1	1.4	.2	66.0	-15.0	-20.5
Chemical	60.5	6.0	1.1	.5	55.1	5.4	8.9	86.0	5.4	1.7	.5	59.2	26.6	32.7
Civil	173.0	10.2	3.3	.7	166.0	7.0	4.0	217.0	10.4	4.2	.6	184.0	33.0	15.2
Electrical/ electronic	335.0	14.0	7.0	.9	324.4	10.6	3.2	367.0	15.4	6.0	1.2	400.0	-11.0	-3.4
Industrial	116.0	4.0	2.3	.2	113.3	4.7	4.0	129.4	4.1	3.0	.3	125.0	4.4	3.4
Mechanical	221.0	11.4	4.3	.9	208.5	12.5	5.7	268.3	12.0	5.2	1.1	236.0	32.3	12.0
Metallurgical	17.0	1.4	.3	.0	16.0	1.0	5.9	23.1	1.4	.4	.1	17.4	5.7	24.7
Mining/ petroleum	26.0	2.0	.5	.0	26.1	.1	.4	36.0	2.2	.7	.1	31.2	4.6	13.3
Engineers, n.e.c.	206.1	13.4	4.0	3.0	184.0	22.1	10.7	276.0	14.0	6.3	3.0	197.4	76.6	26.5
Computer specialists[1]	435.0	9.9	6.7	.6	443.0	-8.0	-2.0	463.1	14.0	9.1	1.3	590.0	-126.9	-27.4

[1]Includes both computer systems analysts and computer programmers.

NOTES: OPTIM/LOW indicates high-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-12. Supply/demand balance of scientists and engineers based on new entrants and immigrants supply model: 1981 and 1987—OPTIM/HIGH

[In thousands]

Occupation	1981							1987						
	Total supply	Supply components: New entrants	Attrition	Immigration	Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply	Total supply	Supply components: New entrants	Attrition	Immigration	Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply
Total scientists	573.0	85.0	9.7	2.3	508.3	64.7	11.2	1,047.5	94.8	19.2	3.0	584.7	462.8	44.2
Agricultural	25.0	5.3	.4	.2	17.6	7.4	29.6	53.2	5.0	1.0	.2	18.4	34.8	65.4
Biologists	71.1	19.0	1.0	.2	55.4	15.7	22.1	177.4	20.2	3.2	.3	62.5	114.9	64.6
Chemists	98.6	6.0	1.9	.8	93.7	4.9	5.0	129.6	6.6	2.5	1.0	102.8	26.8	20.7
Geologists	43.2	4.1	.8	.1	40.6	2.6	6.0	66.1	4.8	1.2	.2	47.9	18.2	27.5
Mathematical	56.9	5.8	1.0	.1	51.8	5.1	9.0	85.2	6.0	1.6	.2	60.6	24.6	28.9
Physicists	23.1	2.8	.4	.2	21.1	2.0	8.6	39.0	3.2	.7	.2	24.2	14.8	37.9
Other life and physical	28.6	1.9	.5	.1	28.2	.4	1.4	37.4	2.1	.7	.1	31.3	6.1	16.3
Social	226.5	40.1	3.7	.6	199.9	26.6	11.7	459.6	46.9	6.3	.8	237.0	222.6	48.4
Economists	49.6	7.1	.9	.3	30.2	19.4	39.1	93.8	8.4	1.7	.3	36.2	57.6	61.4
Psychologists	93.5	12.5	1.6	.2	88.3	5.2	5.6	164.5	15.1	3.0	.3	106.2	58.3	35.4
Sociologists	11.9	5.6	.1	.0	9.2	2.7	22.7	51.3	7.6	.9	.0	10.7	40.6	79.1
Social, n.e.c.	71.5	14.9	1.1	.1	72.2	-.7	-1.0	150.0	15.8	2.7	.2	83.9	66.1	44.1
Total engineers	1,223.7	63.5	23.5	7.0	1,155.6	68.1	5.6	1,507.5	69.2	29.1	7.0	1,423.1	84.4	5.6
Aeronautical/ astronautical	68.6	1.9	1.4	.1	63.2	5.4	7.9	73.9	2.4	1.4	.2	109.2	-35.3	-47.8
Chemical	60.5	5.6	1.1	.5	55.1	5.4	8.9	88.2	5.6	1.7	.5	60.9	27.3	31.0
Civil	173.0	10.2	3.3	.7	165.5	7.5	4.3	217.7	10.6	4.2	.8	188.9	28.8	13.2
Electrical/ electronic	334.6	13.6	6.5	.9	324.4	10.2	3.0	389.7	16.1	7.6	1.3	420.6	-30.9	-7.9
Industrial	117.8	4.0	2.3	.2	113.3	4.5	3.8	130.0	4.2	2.6	.3	130.8	-.8	-.6
Mechanical	220.9	11.4	4.2	.9	208.5	12.4	5.6	270.1	12.3	5.2	1.1	248.2	21.9	8.1
Metallurgical	16.6	1.4	.3	.1	15.6	1.0	6.0	23.2	1.4	.4	.1	18.5	4.7	20.2
Mining/ petroleum	25.6	2.0	.5	.9	26.1	-.5	-2.0	35.9	2.2	.7	.1	31.6	4.3	12.0
Engineers, n.e.c.	206.1	13.4	3.9	2.7	183.9	22.2	10.8	278.8	14.4	5.3	2.6	214.4	64.4	23.1
Computer specialists[1]	434.9	9.9	8.6	.8	442.9	-8.0	-1.8	465.6	14.3	9.2	1.4	603.8	-138.2	-30.0

[1]Includes both computer systems analysts and computer programmers.

NOTES: OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-13. Projected supply of scientists and engineers based on net-mobility supply model: 1983 and 1987—STAG/LOW

[In thousands]

Occupation	1983 Total supply	1983 Supply components: New entrants	1983 Net-mobility	1983 Attrition	1983 Immigration	1987 Total supply	1987 Supply components: New entrants	1987 Net-mobility	1987 In-mobility	1987 Attrition	1987 Immigration
Total scientists	560.6	87.0	---	4.5	2.5	612.1	91.2	---	---	2.5	2.8
Agricultural	20.6	5.3	-4.5	.1	.2	21.2	4.9	-5.1	.0	.1	.2
Biologists	67.1	19.2	-15.2	.4	.2	73.1	19.6	-18.3	.0	.2	.2
Chemists	94.3	6.1	-5.6	.7	.9	99.8	6.4	-5.3	.3	.5	1.0
Geologists	45.2	4.4	-3.2	.3	.2	51.6	4.8	-3.1	.1	2	.2
Mathematical	54.7	5.8	-4.4	.2	.1	59.6	5.8	-4.4	.1	.2	.2
Physicists	23.2	2.9	-2.1	.2	.2	24.9	3.0	-2.6	.0	.1	.2
Other life and physical	29.7	1.9	-1.2	.2	.1	31.5	2.0	-1.4	.2	2	.1
Social	225.8	41.4	---	---	.6	250.4	44.7	---	---	1.0	.7
Economists	34.6	7.5	-5.7	.3	.2	39.4	8.2	-7.2	.0	.1	.3
Psychologists	97.6	12.9	-8.5	1.1	.2	108.2	14.2	-10.7	.0	.5	.2
Sociologists	12.5	6.1	-4.9	.1	.0	14.5	7.2	-6.9	.0	.0	.0
Social, n.e.c.	81.1	14.9	-10.7	.8	.1	88.3	15.1	-12.7	.0	.3	.2
Total engineers	1,194.0	63.9	---	18.8	6.1	1,319.1	64.8	---	---	12.8	6.7
Aeronautical/astronautical	67.0	1.9	1.6	1.1	.1	83.6	2.0	3.8	9 2	.9	.1
Chemical	57.2	5.5	-4.2	.8	.5	60.8	5.4	-4.4	.0	.5	.5
Civil	168.9	10.2	-5.8	2.7	.7	177.0	10.1	-6.1	.8	1.7	.8
Electrical/electronic	343.0	13.9	1.9	5.5	.9	397.9	15.1	3.6	15.6	4.1	1.2
Industrial	112.1	4.0	-1.9	1.8	.2	120.2	4.0	-.8	9.7	1.3	.3
Mechanical	213.2	11.4	-5.6	3.4	.9	230.5	11.4	-5.1	3.6	2.2	1.0
Metallurgical	15.9	1.4	-1.0	.2	.1	17.1	1.3	-1.0	.1	.1	.1
Mining/petroleum	28.2	2.1	-1.3	.4	.1	32.6	2.2	-.9	1.1	.3	.1
Engineers, n.e.c.	188.5	13.5	-10.7	2.9	2.6	199.4	13.3	-10.9	5.3	1.7	2.6
Computer specialists[1]	473.7	10.7	10.6	2.4	.9	568.4	13.2	14.5	59.0	2.3	1.2

[1]Includes both computer systems analysts and computer programmers. Because of rounding, components may not correspond to totals

NOTES: STAG/LOW indicates low-economic growth/low-defense expenditure scenario.

SOURCE: National Science Foundation

Table B-14. Projected supply of scientists and engineers based on net-mobility supply model: 1983 and 1987—OPTIM/HIGH

[In thousands]

Occupation	1983					1987					
	Total supply	Supply components				Total supply	Supply components				
		New entrants	Net-mobility	Attrition	Immigration		New entrants	Net-mobility	In-mobility	Attrition	Immigration
Total scientists	557.5	87.0	----	4.5	2.5	607.6	92.2	----	----	3.0	3.0
Agricultural	20.7	5.3	-4.6	.1	.2	21.3	5.0	-5.1	.0	.1	.2
Biologists	66.8	19.2	-15.6	.4	.2	72.6	19.7	-18.5	.9	.2	.3
Chemists	94.4	6.1	7.2	.7	.9	99.7	6.4	-5.2	.3	.5	1.0
Geologists	45.3	4.4	-1.9	.3	.2	50.1	4.9	-3.8	.1	.2	.2
Mathematical	54.3	5.8	-5.2	.3	.2	59.5	5.9	-4.3	.1	.2	.2
Physicists	23.1	2.9	-2.4	.2	.2	25.2	3.1	-2.6	.0	.1	.2
Other life and physical	29.7	1.9	-1.6	.2	.1	31.7	2.0	-1.4	.2	.2	.1
Social	223.2	41.4	-31.3	2.3	.5	247.5	45.2	----	----	1.4	.8
Economists	34.1	7.5	-6.1	.3	.2	38.7	8.2	-7.3	.0	.2	.3
Psychologists	96.5	12.9	-8.5	1.1	.2	106.2	14.3	-11.0	.0	.7	.3
Sociologists	12.4	6.1	-5.0	.1	.0	14.4	7.3	-6.9	.0	.0	.0
Social, n.e.c.	80.2	14.9	-11.7	.8	.1	88.2	15.4	-12.9	.0	.5	.2
Total engineers	1,181.5	64.0	----	19.1	6.2	1,343.6	66.8	----	----	12.9	6.8
Aeronautical/ astronautical	65.1	1.9	.2	1.1	.1	94.1	2.2	7.3	12.4	1.0	.2
Chemical	57.1	5.5	-5.3	.9	.5	60.9	5.4	-4.4	.0	.5	.5
Civil	167.5	10.2	-8.3	2.7	.7	176.8	10.2	-6.4	.8	1.7	.8
Electrical/electronic	334.7	14.0	-4.9	5.4	1.0	398.8	15.6	4.5	16.4	4.0	1.2
Industrial	111.9	4.0	-4.4	1.9	.2	121.9	4.1	-.3	10.0	1.3	.3
Mechanical	212.3	11.4	-10.2	3.5	.9	233.5	11.7	-4.6	4.0	2.2	1.0
Metallurgical	15.9	1.4	-1.4	.2	.1	17.4	1.4	-.9	.1	.1	.1
Mining/petroleum	28.1	2.1	.5	.4	.1	31.5	2.3	-1.4	.8	.3	.1
Engineers, n.e.c.	188.9	13.5	-14.1	3.0	2.6	208.7	13.9	-9.5	7.4	1.8	2.6
Computer specialists[1]	456.2	10.8	-.6	2.3	.9	550.6	13.5	14.0	59.4	2.2	1.2

[1]Includes both computer systems analysts and computer programmers.

NOTE. STAG/HIGH indicates low-economic growth/high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

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Table B-15. Projected supply of scientists and engineers based on net-mobility supply model: 1983 and 1987—OPTIM/LOW

[In thousands]

Occupation	1983					1987					
	Total supply	Supply components				Total supply	Supply components				
		New entrants	Net-mobility	Attrition	Immigration		New entrants	Net-mobility	In-mobility	Attrition	Immigration
Total scientists	564.4	86.5	----	4.4	2.7	827.1	91.8	----	----	2.5	3.0
Agricultural	20.8	[illegible]	-4.2	.1	.2	22.0	5.0	-5.0	.0	.1	.2
Biologists	87.5	[illegible].1	14.8	.4	.2	75.1	19.7	-18.2	.0	.2	.3
Chemists	95.3	8.1	-4.7	.7	.9	102.5	6.4	-5.4	.4	.5	1.0
Geologists	45.8	4.3	2.8	.3	.2	51.0	4.8	-3.2	.1	.2	.2
Mathematical	54.9	5.8	-4.1	.2	.2	60.8	5.8	-4.3	.2	.2	.2
Physicists	23.4	2.9	-1.9	.2	.2	25.8	3.0	-2.8	.0	.1	.2
Other life and physical	30.0	1.9	-.9	.2	.1	32.4	2.0	-1.4	.2	.2	.1
Social	227.0	41.2	----	2.3	.7	257.7	45.1	----	----	1.0	.8
Economists	34.7	7.5	-5.5	.3	.3	40.1	8.2	[illegible]7.1	.0	.1	.3
Psychologists	98.2	12.8	-8.0	1.1	.2	112.4	14.4	-10.2	.0	.5	.3
Sociologists	12.5	6.1	-4.8	.1	.0	14.9	7.3	-6.9	.0	.0	.0
Social, n.e.c.	81.8	14.8	-10.2	.8	.2	90.3	15.2	-12.9	.0	.4	.2
Total engineers	1,208.2	63.7	----	19.9	8.2	1,360.5	65.8	----	----	13.3	6.7
Aeronautical/astronautical	67.4	1.9	1.8	1.1	.1	88.1	2.0	3.9	9.1	.9	.1
Chemical	57.8	5.5	-3.6	.9	.5	82.7	5.4	-4.4	.1	.5	.5
Civil	171.2	10.2	-3.6	2.7	.7	185.7	10.3	-5.7	1.4	1.8	.8
Electrical/electronic	344.8	13.9	3.3	5.5	1.0	402.2	15.1	2.4	15.2	4.1	1.2
Industrial	113.5	4.0	-.7	1.8	.2	124.4	4.1	-.7	9.9	1.3	.3
Mechanical	218.5	11.4	-2.7	3.4	.9	242.3	11.7	-4.8	5.0	2.4	1.0
Metallurgical	16.2	1.3	-.7	.2	.1	18.2	1.4	-.9	.2	.2	.1
Mining/petroleum	28.4	2.1	-1.1	.4	.1	32.2	2.2	-1.0	1.0	.3	.1
Engineers, n.e.c.	190.4	13.4	-9.1	2.9	2.8	206.7	13.8	-11.0	6.4	1.8	2.6
Computer specialists[1]	476.3	10.8	13.0	2.4	.9	580.4	13.3	14.5	80.4	2.3	1.2

[1] Includes both computer systems analysts and computer programmers.

NOTE: OPTIM/LOW indicates high-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-16. Projected supply of scientists and engineers based on net-mobility supply model: 1983 and 1987—OPTIM/HIGH

[In thousands]

Occupation	1983 Total supply	1983 Supply components: New entrants	1983 Supply components: Net-mobility	1983 Supply components: Attrition	1983 Supply components: Immigration	1987 Total supply	1987 Supply components: New entrants	1987 Supply components: Net-mobility	1987 Supply components: In-mobility	1987 Supply components: Attrition	1987 Supply components: Immigration
Total scientists	566.2	87.1	----	4.4	2.7	839.9	93.7	----	----	2.5	3.0
Agricultural	20.8	5.3	-4.2	.1	.2	22.2	5.1	-5.0	.0	.1	.2
Biologists	87.6	19.2	-14.8	.4	.2	76.3	20.0	-18.3	.0	.2	.3
Chemists	95.5	6.2	-4.5	.7	.9	104.8	6.5	-5.1	.5	.5	1.0
Geologists	45.7	4.4	-2.7	.3	.2	51.8	4.8	-3.2	.1	.2	.2
Mathematical	55.3	5.8	-3.8	.2	.2	63.0	6.0	-4.0	.3	.2	.2
Physicists	23.6	2.9	-1.8	.2	.2	26.6	3.1	-2.5	.0	.1	.2
Other life and physical	30.1	1.9	-.8	.2	.1	33.3	2.1	-1.3	.0	.2	.1
Social	227.6	41.4	----	2.3	.7	262.3	48.1	----	----	1.0	.8
Economists	34.7	7.5	-5.5	.3	.3	40.7	8.4	-7.2	.0	.1	.3
Psychologists	98.4	12.9	-7.9	1.1	.2	113.6	14.7	-10.2	.0	.5	.3
Sociologists	12.5	8.1	-4.8	.1	.0	15.1	7.4	-7.0	.0	.0	.0
Social, n.e.c.	82.0	14.9	-9.9	.8	.2	92.8	15.6	-12.8	.0	.4	.2
Total engineers	1,217.2	84.2	----	18.9	6.3	1,437.3	68.1	----	----	14.0	6.9
Aeronautical/ astronautical	70.0	1.9	4.3	1.1	.1	104.8	2.3	7.6	13.1	1.1	.2
Chemical	58.0	5.5	-3.4	.9	.5	64.2	5.5	-4.2	.1	.5	.5
Civil	171.6	10.2	-3.3	2.7	.7	190.1	10.5	-4.8	1.8	1.8	.8
Electrical/electronic	347.9	14.0	6.2	5.5	1.0	421.3	15.7	5.3	18.7	4.3	1.2
Industrial	114.2	4.0	.0	1.8	.3	129.8	4.2	.3	11.3	14	.3
Mechanical	217.9	11.5	-1.4	3.4	.9	253.4	12.1	-2.8	7.0	2.5	1.1
Metallurgical	16.3	1.4	-.6	.2	.1	19.2	1.4	-.7	.4	.2	.1
Mining/petroleum	28.5	2.1	-1.0	.4	.1	32.5	2.2	-1.0	1.1	.3	.1
Engineers, n.e.c.	192.8	13.8	-7.0	2.9	2.6	222.0	14.2	-8.8	9.7	1.9	2.6
Computer specialists[1]	477.7	10.9	14.2	2.4	.9	592.8	13.8	18.9	63.8	2.4	1.2

[1]Includes both computer systems analysts and computer programmers.

NOTES OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-17. Supply/demand balance of scientists and engineers based on net-mobility supply model: 1983 and 1987—STAG/LOW

[In thousands]

Occupation	1983 Supply	1983 Demand	1983 Balance surplus (+)/ shortage (-)	1983 Balance as percent of supply	1987 Supply	1987 Demand	1987 Balance surplus (+)/ shortage (-)	1987 Balance as percent of supply
Total scientists	560.6	513.8	46.8	8.3	612.1	555.9	56.2	9.2
Agricultural	20.6	17.2	3.4	16.5	21.2	17.3	3.9	18.4
Biologists	67.1	55.9	11.2	16.7	73.1	59.4	13.7	18.7
Chemists	94.3	91.9	2.5	2.6	99.8	97.7	2.1	2.1
Geologists	45.2	41.7	3.5	7.1	51.6	47.9	3.7	7.2
Mathematical	54.7	52.0	2.7	4.9	59.6	56.9	2.7	4.5
Physicists	23.2	21.2	2.0	8.6	24.9	22.4	2.5	10.0
Other life and physical	29.7	28.0	1.7	5.7	31.5	29.5	2.0	6.3
Social	225.8	205.9	19.9	8.8	250.4	224.8	25.6	10.2
Economists	34.6	31.1	3.5	10.0	39.4	34.8	4.6	11.7
Psychologists	97.6	91.5	6.1	6.3	108.2	100.5	7.7	7.1
Sociologists	12.5	9.4	3.1	24.6	14.5	10.1	4.4	30.3
Social, n.e.c.	81.1	73.9	7.2	8.9	88.3	79.4	8.9	10.1
Total engineers	1,194.0	1,169.2	24.8	2.1	1,319.1	1,296.4	22.7	1.7
Aeronautical/ astronautical	67.0	67.5	-.5	-.7	83.6	85.5	-1.9	-2.3
Chemical	57.2	54.0	3.2	5.6	60.8	57.4	3.4	5.6
Civil	168.9	166.8	2.1	1.2	177.0	174.7	2.3	1.3
Electrical/electronic	343.0	340.9	2.1	.6	397.9	396.3	1.6	.4
Industrial	112.1	111.4	.6	.6	120.2	120.3	-.1	-.1
Mechanical	213.2	206.6	6.6	3.1	230.5	223.9	6.6	2.9
Metalurgical	15.9	15.1	.8	5.0	17.1	16.3	.8	4.7
Mining/petroleum	28.2	27.1	1.1	3.9	32.6	31.7	.9	2.8
Engineers, n.e.c.	188.5	179.8	8.7	4.6	199.4	190.3	9.1	4.6
Computer specialists[1]	473.7	480.2	-7.2	-1.5	568.4	577.6	-9.2	-1.6

[1]Includes both computer systems analysts and computer programmers.

NOTES. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals

SOURCE: National Science Foundation

Table B-18. Supply/demand balance of scientists and engineers based on net-mobility supply model: 1983 and 1987—STAG/HIGH

[In thousands]

Occupation	1983				1987			
	Supply	Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply	Supply	Demand	Balance surplus (+)/ shortage (-)	Balance as percent of supply
Total scientists	557.5	507.6	49.9	9.0	607.5	567.4	40.1	36.6
Agricultural	20.7	17.2	3.5	16.9	21.3	17.5	3.7	17.4
Biologists	66.8	55.3	11.5	17.2	72.6	60.4	12.2	16.8
Chemists	94.4	90.7	3.7	3.9	99.7	99.6	.1	.0
Geologists	45.3	42.7	2.6	5.7	50.1	48.2	1.9	3.8
Mathematical	54.3	51.0	3.3	6.1	59.5	58.7	8	1.3
Physicists	23.1	20.9	2.2	9.5	25.1	23.4	1.7	6.8
Other life and physical	29.7	27.6	2.1	7.1	31.7	30.4	1.3	4.1
Social	223.2	202.2	21.0	9.4	247.5	229.2	18.3	7.4
Economists	34.1	30.3	3.8	11.1	38.7	35.3	3.4	8.8
Psychologists	96.5	90.4	6.1	6.3	106.2	101.7	4.5	4.2
Sociologists	12.4	9.3	3.1	25.0	14.4	10.3	3.1	21.5
Social, n.e.c.	80.2	72.2	8.0	10.0	88.2	81.9	6.3	7.1
Total engineers	1,181.5	1,140.3	41.2	3.5	1,343.6	1,373.2	-29.6	2.2
Aeronautical/astronautical	65.1	64.5	.6	.9	94.1	107.2	-13.1	-13.9
Chemical	57.1	53.1	4.0	7.0	60.9	56.7	2.2	3.6
Civil	167.5	163.5	4.0	2.4	176.8	179.1	-2.3	-1.3
Electrical/electronic	334.7	327.6	7.1	2.1	398.8	415.2	-16.4	-4.1
Industrial	111.9	109.3	2.6	2.3	121.9	125.0	-3.1	-2.5
Mechanical	212.3	202.2	10.1	4.8	233.5	233.4	.1	.0
Metallurgical	15.9	14.8	1.1	6.9	17.4	17.1	.3	1.7
Mining/petroleum	28.1	27.6	.5	1.8	31.5	31.8	-.3	.0
Engineers, n.e.c.	188.9	177.7	11.2	5.9	208.7	205.7	3.0	1.4
Computer specialists[1]	456.2	454.3	1.9	-.4	550.6	588.9	-38.3	-7.0

[1] Includes both computer systems analysts and computer programmers.

NOTES. STAG/LOW indicates low-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-19. Supply/demand balance of scientists and engineers based on net-mobility supply model: 1983 and 1987—OPTIM/LOW

[In thousands]

Occupation	1983 Supply	1983 Demand	1983 Balance surplus (+)/shortage (-)	1983 Balance as percent of supply	1987 Supply	1987 Demand	1987 Balance surplus (+)/shortage (-)	1987 Balance as percent of supply
Total scientists	564.5	520.4	44.1	7.8	627.1	570.9	56.2	9.0
Agricultural	20.8	17.5	3.3	15.9	22.0	18.1	3.9	17.7
Biologist	67.5	56.6	10.9	16.1	75.1	61.4	13.7	18.2
Chemists	95.3	93.5	1.8	1.9	102.5	100.3	2.2	2.1
Geologists	45.6	42.3	3.3	7.2	51.0	47.3	3.7	7.3
Mathematical	54.9	52.5	2.4	4.4	60.8	58.1	2.7	4.4
Physicists	23.4	21.5	1.9	8.1	25.6	23.1	2.5	9.8
Other life and physical	30.0	28.4	1.6	5.3	32.4	30.3	2.1	6.5
Social	227.2	208.1	19.1	8.4	257.7	232.3	25.4	9.9
Economists	34.7	31.3	3.4	9.8	40.1	35.5	4.6	11.5
Psychologists	98.2	92.5	5.7	5.8	112.4	105.0	7.4	6.6
Sociologists	12.5	9.5	3.0	.2	14.9	10.5	4.4	29.5
Social, n.e.c.	81.6	74.8	6.8	8.3	90.3	81.3	9.0	10.0
Total engineers	1,206.2	1,189.0	17.2	1.4	1,360.5	1,337.0	23.5	1.7
Aeronautical/astronautical	87.4	88.0	-.6	-1.9	86.1	88.0	-1.9	-2.2
Chemical	57.8	55.1	2.7	4.7	62.7	59.2	3.5	5.8
Civil	171.2	170.7	.5	.3	185.7	183.8	1.9	1.0
Electrical/electronic	344.8	343.6	1.2	.3	402.2	399.6	2.6	.6
Industrial	113.5	113.6	-.1	-.1	14.5	124.6	-.1	-.1
Mechanical	216.5	212.0	4.5	2.1	242.3	235.7	6.6	2.7
Metallurgical	16.2	15.6	.6	3.7	18.2	17.4	.8	4.4
Mining/petroleum	28.4	27.5	.9	3.2	32.2	31.2	1.0	3.1
Engineers, n.e.c.	190.4	182.9	7.5	3.9	206.6	197.5	9.1	4.4
Computer specialists[1]	476.3	484.6	-8.3	-1.7	580.4	589.5	-9.1	-1.6

[1] Includes both computer systems analysts and computer programmers.

NOTES. OPTIM/LOW indicates high-economic growth/low-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

Table B-20. Supply/demand balance of scientists and engineers based on net-mobility supply model: 1983 and 1987—OPTIM/HIGH

[In thousands]

Occupation	1983 Supply	1983 Demand	1983 Balance surplus (+)/ shortage (-)	1983 Balance as percent of supply	1987 Supply	1987 Demand	1987 Balance surplus (+)/ shortage(-)	1987 Balance as percent of supply
Total scientists	566.2	523.0	43.2	7.7	639.9	584.7	55.2	8.6
Agricultural	20.8	17.6	3.2	15.4	22.2	18.4	3.8	17.1
Biologists	67.6	56.7	10.9	16.1	76.3	62.5	13.8	18.1
Chemists	95.5	93.9	1.6	1.7	104.6	102.8	1.8	1.7
Geologists	45.7	42.5	3.2	7.0	51.6	47.9	3.7	7.2
Mathematical	55.3	53.0	2.3	4.2	63.0	60.6	2.4	3.8
Physicists	23.6	21.7	1.9	8.1	26.6	24.2	2.4	9.0
Other life and physical	30.1	28.6	1.5	5.0	33.3	31.3	2.0	6.0
Social	227.6	209.0	18.6	8.2	262.3	237.0	25.3	9.6
Economists	34.7	31.4	3.3	9.5	40.7	36.2	4.5	11.1
Psychologists	98.4	92.7	5.7	5.8	113.6	106.2	7.4	6.5
Sociologists	12.5	9.6	2.9	23.2	115.2	110.7	4.5	29.6
Social, n.e.c.	82.0	75.3	6.7	8.2	92.8	83.9	8.9	9.6
Total engineers	1,217.2	1,207.6	9.6	.8	1,437.3	1,423.1	14.2	1.0
Aeronautical/ astronautical	70.0	72.4	-2.4	-3.4	104.8	109.2	-4.4	-4.2
Chemical	58.0	55.4	2.6	4.5	64.2	60.9	3.3	5.1
Civil	171.6	171.5	.1	.1	190.1	188.9	1.2	.6
Electrical/electronic	347.9	348.9	-1.0	-.3	421.3	420.6	.7	.2
Industrial	114.2	114.9	-.7	-.6	129.8	130.8	-1.0	-.8
Mechanical	217.9	214.3	3.6	1.7	253.4	248.2	5.2	2.1
Metallurgical	16.3	15.8	.5	3.1	19.2	18.5	.7	3.6
Mining/petroleum	28.5	27.6	.9	3.2	32.5	31.6	.9	2.8
Engineers, n.e.c.	192.8	186.8	6.0	3.1	222.0	214.4	7.6	3.4
Computer specialists[1]	477.7	486.9	-9.2	-1.9	592.8	603.8	-11.0	-1.9

[1]Includes both computer systems analysts and computer programmers.

NOTES: OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario. Because of rounding, components may not correspond to totals.

SOURCE: National Science Foundation

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