Labor-Market Conditions for Engineers: Is There a Shortage? Proceedings of a Symposium (1984)

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Proceedings of a Symposium

Office of Scientific and Engineering Personnel
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FOREWORD

In an increasingly international world in which rapidly changing technologies are radically transforming lifestyles and workstyles, our technically trained work force is of critical importance in assuring that our social, economic, and cultural well-being continues to improve and that our competitive position is maintained. It was concern about the adequacy of this work force to meet these important objectives that motivated the National Academy of Engineering, in conjunction with the Office of Scientific and Engineering Personnel, to organize a Symposium on Labor-Market Conditions for Engineers.

The issue seems to be a hardy perennial. We experience continuous cycles of perceived surplus and shortage. The basic cause is fairly clear: the demand for engineers fluctuates with rather high frequency, responding to economic conditions and other conditions that seem to change rapidly, while the supply side fluctuates with low frequency. It takes time to train an engineer; and the imbalances resulting when one tries to match a high-frequency demand with a low-frequency supply gives what we see as alternate surpluses and shortages.

There exists today a considerable amount of ambiguity about the condition of this labor market. There was significant evidence of labor-market shortages--particularly in electronics and energy-related fields--as we entered the 1980s. These shortages disappeared in the 1980s as a severe economic downturn was experienced and as the world energy situation was transformed from one of relative scarcity to one of relative abundance.

We are now recovering from the downturn and are facing new government initiatives in defense, space, and other areas that are expected to place large demands on our engineering work force. It is clear that a significant number of programs--the space missile programs, the space station now being proposed for the National Aeronautics and Space Administration, or some of the engineering initiatives being considered at the National Science Foundation--will require engineers and scientists of all kinds. Moreover, there appears to be a more general tendency to seek technological solutions to a number of our national problems. The combined effect of these recent trends could ultimately place severe strains on the capacity of this work force.

A symposium, then, on the supply/demand problems of market conditions is very timely. I know how difficult the problems of prediction are in natural systems. Prediction in human and social systems are much more difficult. Hopefully, the presentations and discussions of the Symposium will reduce the degree of ambiguity surrounding this question and will provide policy-makers with a better factual base on which they can evaluate what action, if any, should be taken.

Robert M. White
President
National Academy of Engineering

ACKNOWLEDGEMENTS

Thanks are due to the National Academy of Engineering for cosponsoring this activity and to those who strongly endorsed the idea of a symposium in the early planning stages, particularly the Committee on Education and Utilization of the Engineer; its chairman, Jerrier Haddad; the Commission on Engineering and Technical Systems; and Kirsten Pollack, CETS associate director for new programs development. Peter Syverson served as staff officer for the symposium and provided strong leadership in planning and implementing this project. Linda Dix capably assured that the logistics were handled smoothly and that the schedule was followed closely and edited the final report. Michael McPherson, Williams College, served as consultant to the project, chairing the symposium. Alan Fechter, executive director of the Office of Scientific and Engineering Personnel (OSEP), and William K. Estes, OSEP's senior consultant, offered invaluable counsel and assistance both during the planning stages and as this manuscript was being organized. In addition, the following staff provided excellent secretarial support to this project: Patricia A. Green, Catherine D. Jackson, Patricia King, Wyetha Turney, and Mary A. Wagner.

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SYMPOSIUM OVERVIEW

Four models of the engineering labor market--those of the American Electronics Association (AEA), the Bureau of Labor Statistics (BLS), the National Science Foundation (NSF), and the American Council on Education's Business-Higher Education (B-HEF)--were examined in depth, and two panels were convened to assess the situation for engineers in academic labor markets and in federal government laboratories. On the demand side of the market, the three comprehensive models (BLS, NSF, and B-HEF) were in reasonable agreement in projecting strong growth. (These forecasts were all based on an assumption that there would not be a repeat of the severe economic downturn experienced in the beginning of the 1980s.) Forecasts of employment growth for all engineering fields over the next five to six years ranged from 26,000 to 48,000, or 2.5 to 4.5 percent per year, depending on the assumption made about aggregate economic growth and real increases (in constant dollars) in defense spending. Growth for electrical/electronics engineers was projected to be slightly higher--ranging from 4 to 5 percent. In addition to this employment growth, new hires would be required to replace currently employed engineers who are expected to leave the work force because of death or retirement or who are expected to move to non-engineering jobs. This expected replacement demand, estimated in three of the four studies examined, far outweighed in importance the demand generated by expected employment growth and ranged from 62,000 to 93,000 annually, or from 6 to 9 percent of the work force depending on the model and economic/defense expenditure scenario examined.

The forecasts developed by the AEA were more tightly focused on electrical and computer engineers. These forecasts indicated much stronger growth than those of the other models--annual growth rates of 10 to 16 percent for electrical and computer engineers, respectively.

On the supply side of this labor market, the studies forecast that only one-tenth to one-half of the projected job openings would be filled by new graduates, depending on field and scenario examined. The critical issue confronted by those who attended the symposium was whether the large difference between the projected number of job openings and the projected number of new graduates entering the field was cause for concern or alarm. The answer depended on how the inflow of experienced workers was treated. All but the AEA study addressed this inflow. BLS and NSF concluded that it would be sufficient in numbers to meet projected requirements in most fields. The studies differed, however, in their conclusions about the qualitative adequacy of this inflow. The B-HEF study implied, by and large, that this inflow would be inferior in quality to those who were already employed and to the newly graduated engineers. The BLS and NSF studies did not explicitly address the quality issue but acknowledged its importance.

Critiques of the Projection Studies

The methods and assumptions of the four studies were examined critically by three discussants. One of the discussants found major needs for improvement in the methods of all of the approaches reported and found little basis for firm conclusions about shortages for engineers. He considered the NSF model, which attempts to incorporate supply adjustments through interoccupational mobility, an important advance in improving our ability to assess labor-market imbalances. A second noted that the various approaches agree reasonably well in their projections of employment growth and numbers of job openings in the field over the next several years but differ considerably in their assumptions and conclusions as to how the demand will be met, particularly in their view of the major role of mobility among fields. He also suggested that models in which supply and demand can respond to market disequilibria (such as that of NSF) require thinking about shortages in terms other than "demand minus supply." The third discussant suggested that there is a limited, but important role that can be played by models based on employer forecasts (such as that of the AEA).

In particular, he stated that such models can be of most value in developing forecasts of short-term hiring plans. He also advocated expansion and refinement of the stock of data describing occupational mobility in order to be able to improve the reliability of projections based on models such as the one described in the NSF paper.

Panel Sessions

Two discussion sessions of the symposium focused on specific areas where shortages of engineers may be particularly severe. The first panel dealt with problems of finding qualified engineering faculty, and all members of the panel indicated concern over the likelihood of shortages in quantity and quality of faculty becoming a severe problem. The second session covered engineering employment in federal laboratories. Reports from representatives of major federal laboratories indicated only limited concern over quantitative shortages in engineering research personnel but increasing problems in holding highly talented younger investigators and attracting "superstar" experienced researchers. Also concern was expressed about the declining proportion of United States citizens earning doctoral degrees in engineering and the consequent increasing reliance on foreign citizen engineers in the laboratories.

Is There a Shortage?

The papers presented, the panels, and the general discussion all pointed to the conclusion that there can be no single or simple answer to the question, "Is there or is there likely to be a shortage of engineers in the U.S.?" Traditionally, the presence or absence of shortages has been defined in terms of employers' demand for workers and numbers of individuals seeking employment. However, it is becoming increasingly recognized that economic efficiency and level of performance by engineers and other research personnel are not necessarily maximized when supply and demand are in numerical balance. Quality of specialized work forces is a major problem that has had insufficient study. Meeting local shortages by the transfer of individuals from other occupations may have effects both on the quality of work in the receiving field and on the loss of talent from the donor field.

Also, shortages may become manifest not so much in job vacancies as in increased length and cost of search processes to find appropriate people to fill specific jobs. Finally, mobility between fields required to meet local shortages may lead to breakdowns of normal career paths, which may lead to increased costs both to workers and employers and to detrimental effects on future capabilities of the system to meet emerging needs. These quality-related problems may be of special importance in relation to the competitive position of the United States in world economic markets.

INTRODUCTION

The engineering labor market has been subject to a number of unusual pressures over the last decade. The demand for bachelor's-level engineers has rebounded strongly from the depressed conditions of the early 1970s. This high demand, spurred by both industry and government (particularly with the recent defense build-up), has stimulated unprecedented levels of undergraduate engineering enrollment and, hence, very strong demand for engineering faculty, especially in electrical and computer engineering.

Opinions differ about what these trends imply for the future of the engineering labor market. Forecasts based on employers' projections of needs for engineers suggest that bachelor's-level engineers will remain in short supply despite high enrollment levels. Other forecasts that derive estimates of the demand for engineers from econometric models of the U.S. economy suggest instead an overall balance in the supply and demand for engineers, with spot shortages in some critical fields like computer engineering and possible surpluses in other fields. Adjustments in the engineering labor market have in the past relied importantly on movements of personnel among engineering fields and between engineering and other scientific fields, in addition to new engineering graduates. Whether the engineering labor market will continue to rely heavily on mobile personnel in adjusting to changing conditions and, if so, what patterns of mobility will occur are further important questions about this labor market. The implications of such mobility of personnel for the quality of the engineering work force are an important concern among observers of this labor market.

High levels of industrial demand for engineers raise special personnel problems both for academic engineering departments and for federal research laboratories. The federal labs must compete in a tight labor market for highly trained personnel with private firms that may have more flexibility in offers of salary and working conditions. Engineering departments at universities are faced with the double bind of needing to compete in that tight labor market for faculty at the same time that the same labor market adds to requirements for faculty by boosting engineering enrollments. And universities may be limited by rules and traditions governing equity in payment across academic specialties in the salary offers and working conditions they can make available to engineers.

The Office of Scientific and Engineering Personnel (OSEP), recognizing the degree of controversy and concern surrounding these issues, arranged this Symposium on Labor-Market Conditions for Engineers, held on February 2, 1984, as a way of exploring them further. The symposium's primary purpose was to encourage a close examination of the methodology, assumptions, and conclusions developed in recent projection models of the engineering labor market. Improved understanding of how this labor market works and is likely to work in the future is the essential basis for intelligent policy making. The symposium therefore centered around presentation and critical analysis of the most widely cited recent models of the engineering labor market. The projection analyses of the Bureau of Labor Statistics, the National Science Foundation, the Business-Higher Education Forum, and the American Electronics Association were described for the symposium audience by persons closely involved in their development. The models were then subjected to close comparison and criticism by a set of knowledgeable commentators. The special problems of the federal research laboratories and of engineering faculty were the focus of separate panel presentations and discussion in the course of the symposium. The program included opportunities throughout the day for questions and comments from the audience, which included a number of very knowledgeable persons in the field.

Policy-makers, employers, educators, and individual engineers depend heavily on labor-market forecasts in trying to plan responsibly for the future. It is often difficult for decision-makers to know how to proceed in the face of forecasts that disagree (or appear to disagree) and also to make sensible judgments about how much confidence to attach to various aspect of forecasts. Another major goal of the symposium was to help such decision-makers to understand better why forecasts diverge when they do and, perhaps even more important, to distinguish those areas where there is strong and confident agreement among forecasters from those where there is real disagreement or considerable shared uncertainty about the future.

Still another goal of the symposium was to help advance the art of forecasting itself. The process of mutual comparison and criticism is vital to all scientific endeavor, including that of improving forecasters' methods and results. Moreover, bringing model builders into conversation with the "consumers" of the modelers' products brings important benefits as well. Not only may the consumers come away with a better understanding of the models' strengths and limitations, the forecasters may also come to a greater appreciation of the uses to which their analyses are put. This can help guide them in focusing their work in more productive directions and make them more aware of which assumptions in their models are most troubling or critical from the users' point of view.

OSEP and its predecessor organization, the Commission on Human Resources, have for some time viewed it as an important part of their mission to promote this sort of constructive interchange among labor-market analysts and between analysts and decision-makers. An earlier venture along these lines was the Workshop for Forecasters of Demand for Scientists and Engineers conducted in 1978 as part of the work of the Committee on Continuity in Academic Research Performance. That workshop--narrower than the present symposium in focusing almost exclusively on Ph.D. scientists and engineers but broader in examining the whole range of scientific and engineering fields, rather than concentrating mainly on engineers--was instrumental in discovering some important areas of agreement among competing models of the demand for Ph.D. scientists and engineers, in isolating and clarifying some specific areas of disagreement, and in advancing the methodological discussion of forecasting the Ph.D. labor market. These contributions were significant both in advancing the policy debate and in encouraging improved modeling efforts in this field. OSEP hopes that the present symposium will prove similarly useful in the engineering field and looks forward in the future to convening similar workshops and symposia when developments warrant.

This volume of Proceedings aims to provide an accurate record of the presentations and discussions (summarized as noted in the Contents) that occurred at the symposium. A number of the participants in the symposium hold strong views on policy toward the engineering labor market, and these views both color their interpretations of available data and structure their opinions about where future analytical efforts should lie. An understanding of these sometimes controversial perspectives is important in gaining a full grasp on the analytical and empirical issues at stake in these discussions. In presenting a full and frank portrait of the views aired at the symposium, OSEP implies no endorsement of those views. Throughout these Proceedings, all findings and opinions are identified as those of particular speakers and should be attributed to them and not to the NRC.

The symposium was the product of a great deal of thought and effort on the part of all the participants. The day proved lively and at times contentious, but--thanks to the discipline and careful preparation of the speakers and commentators--discussion also remained remarkably well-focused around a limited set of important themes. OSEP is proud and pleased to be able to convey the results of the day's discussions to a wider audience.

PAPERS PRESENTED

TECHNICAL EMPLOYMENT PROJECTIONS, 1983-198~~5~~7: A SUMMARY

Pat Hill Hubbard
Vice President, Engineering Education
American Electronics Association

Introduction

I am really pleased at this opportunity to present a summary of the American Electronics Association's (AEA) report, _Technical Employment Projections: 1983-87_.

Before I get into data, I would like to tell you briefly about AEA and why we have done this survey. AEA is a non-profit trade association of more than 2,400 growing high-technology companies throughout the country. Our membership includes all segments of the U.S. electronics and information technologies industry--including computers, telecommunications, defense, instruments, semiconductors, software, research, aerospace, and office systems. While AEA numbers among its members many of the largest electronics manufacturers, nearly three-quarters of our companies are relatively young, fast-growing businesses currently employing fewer than 250 people. In aggregate, AEA companies employ over 1.5 million Americans. The purpose of our association is to insure a healthy climate in which our companies can continue to grow and expand and conduct business economically and profitably.

Three years ago companies around the country complained to our national Board of Directors that an inability to find sufficient qualified electrical and computer engineers was jeopardizing the industry's economic competitiveness. The Board appointed a Blue Ribbon Committee to study the problem, determine its degree, and recommend an action plan to redress it.

This committee decided that--in spite of studies by the Bureau of Labor Statistics, the National Science Foundation, and the Engineering Manpower Commission--a missing piece of the picture was the perspective of hightech company management on the need for technical people.[1] This focus was especially needed about electrical and computer engineers--the two key engines of high-technology growth. AEA also believed--and I personally have a very strong view on this--that industry owed education and government planners some trend data on the types and numbers of people that it expects to need with lead time sufficient to do something about it. For these reasons, we undertook a survey of our membership in 1981 and repeated it with minor modifications this last spring.

Survey Respondents

The latest data come from 815 respondents, or 39 percent of those companies sent questionnaires. Respondents represent 736,129 employees as of December 1982 and $56.4 billion in total sales for their most current fiscal year. Six participants did not break out data by geographical area, and therefore, are included only in the U.S. aggregate. Six did not break out figures by job categories but provided them in totals under the categories "professional" and "paraprofessional." Calculated in the data also are 15 respondents who provided negative projections in areas where they expect to cut back their work force. The data reflect perhaps not an increase in job growth, but a change in the mix of technical categories.

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[1] Members of the National Advisory Committee were as follows: Richard Atkinson (chancellor, University of California-San Diego); Joseph A. Boyd (chairman, Harris Corporation); John M. Fluke (chairman, John Fluke Mfg. Co., Inc.); Dr. C. Lester Hogan (director, Fairchild Camera & Instrument Corp.); Dr. Robert N. Noyce (vice chairman, Intel Corporation); Dr. William J. Perry (partner, Hambrecht & Quist); Dr. Joseph Pettit (president, Georgia Institute of Technology); Dr. Allen E. Puckett (chairman, Hughes Aircraft Company); Ray Stata (chairman and president, Analog Devices, Inc.); Dr. Dean A. Watkins (chairman, Watkins-Johnson Company); Dr. Karl Willenbrock (Green Professor of Engineering, Southern Methodist University); John A. Young (president and chief executive officer, Hewlett-Packard Co.).

Respondents as Percentage of Entire U.S. Industry

Based on Department of Commerce and proprietary AEA data, the U.S. electronics industry in 1982 employed 2.23 million people and had total annual sales of $187 billion. Assuming that survey participants in size and sales are generally representative of the broader U.S. industry, in aggregate their data represents about 30 percent of the U.S. electronics industry.

Company Methodology for Projections

794 facilities reporting

	Business Plan		Projected Sales		Growth History		Educated Guess	
YEAR	No.	(%)	No.	(%)	No.	(%)	No.	(%)
1983	514	64.7	165	20.8	42	5.3	73	9.2
1984	332	42.5	269	34.5	40	5.1	140	17.9
1985	252	33.4	181	24.0	70	9.3	251	33.3
1986-87	181	24.7	114	15.7	35	4.8	398	54.8

The majority of survey respondents used some kind of thoughtful plan as a basis for the first three years' projections. Reliance on a business plan, for example, was used by 65 percent the first year, 42 percent the second year, 33 percent the third year, and 25 percent for years four and five. While the majority relied on a business plan for years one and two, one-third relied on a business plan and one-third on an educated guess for year three; and 55 percent did use educated guesses for years four and five; you have to keep that in mind as you look at the data. Growth history was used least in each of the five years.

Respondents' Perceptions of the Economy

In an optional question, respondents were asked to rate their perceptions of the economy through 1987 on a scale of 1 (poor) to 10 (excellent). Predictably, pessimistic perceptions decreased steadily: 50% (1982); 18.3% (1983); 4.4% (1984); 2.3% (1985); and 1.8% (1986-1987).

Optimistic perceptions steadily increased: 2% (1982); 5.6% (1983); 16.5% (1984); 31.2% (1985); and 38.3% (1986-1987). Fifty-one percent, however, still expect an "average" economy even in 1986-1987.

Participants by Job Title

The breakout by title of respondent points out the difference in perspective presented by AEA respondents and those of other survey organizations:

Number	Percentage	Title Of Respondent
97	11.9	CEOs (President, Chairman, General Manager)
498	61.1	Personnel (any level or function in Personnel, Human Resources, or Industrial Relations)
16	2.0	Planning (Corporate, Strategic, Manpower Human Resource Planning)
45	5.5	Engineering (any level)
54	6.6	Finance (any level or function, including Controller, Accountant, Chief Financial Officer, etc.)
105	12.9	Other (Administration, Operations, Statistician, Administrative Assistant, etc.)
815	100%	TOTAL RESPONDENTS

Almost 12 percent were filled out by actual CEOs, chairmen, general managers, presidents. The majority, about 61 percent, were filled out by people in personnel (human resources, industrial relations, and so forth).

Methods of Computing Data

The data is reported in three ways: (1) the actual number of new jobs projected by participants, (2) the annual compounded growth rates (ACGR), and (3) simple percentage of growth (five-year totals). The sample size of participants decreases slightly each year. Percentages have been adjusted on the assumption that the few companies with missing data follow the same trends as those who provided it. Projection figures are for new job growth only and do not reflect replacements due to retirement, death, turnover, or promotion into management.

Data Not Weighted by Regions

This data, like that previously, continues weighted by West Coast respondents (49.6%). We had 14 percent this time from New England, which is at least a 60 percent increase; and we had 12 percent from the Southwest. However, regional comparisons can be made broadly by using percentages of growth, minimizing imbalances in numbers reporting within regions.

Reducing Duplication of Defense Contract Projections

In an effort to counter possible duplication of projections among defense contractors vying for the same contract, respondents were asked to indicate the percentage of projections based on receiving anticipated defense contracts. Two-thirds of all participants reported no percentage. Percentages by those remaining, when combined, result in 16 percent of the projections for the total 815 being based on anticipated defense contracts. This percentage correlates closely with a recent SRI study that shows 17 percent of all Silicon Valley sales and manufacturing jobs as defense-based. For every $100, $17 is based on defense in Silicon Valley.

It is AEA's view that companies exercise sophisticated judgments regarding successful competition for defense contracts and that many had already filtered out projections for contracts that they were unlikely to receive. However, for those who prefer to do so, data should be reduced by 16 percent to eliminate any possible duplication.

TABLE 1. U.S. Job Growth Projections

	Current	Projected Additional				Projection Totals	Simple %[4]
	Dec. 1982	1983	1984	1985	1986–87		ACGR[5]
TOTAL TECHNICAL AND NON-TECHNICAL EMPLOYEES							
Total Employees	736,129	57,999	67,099	84,235	125,725	335,058	49.0% 8.3%
TECHNICAL PROFESSIONALS[1]							
Electronic/Electrical Engineers	52,261	6,503	6,483	6,872	12,314	32,172	65.5% 10.6%
Software Engineers	21,806	4,376	4,339	4,959	9,705	23,379	115.0% 16.5%
Mechanical Engineers	12,694	1,646	1,252	1,476	2,516	6,890	58.8% 9.7%
Industrial/Manufacturing Engineers	9,431	1,319	1,264	1,331	2,030	5,944	67.5% 10.9%
Other Engineers	31,887	3,023	1,887	2,280	4,350	11,540	40.0% 7.0%
Computer Analysts/ Programmers	10,567	2,088	1,930	2,135	3,915	10,088	102.5% 15.2%
Electronic Engineering Technologists	7,607	1,343	1,531	1,665	2,915	7,454	107.0% 15.7%
Other Technical Professionals	16,283	1,773	1,704	1,936	3,240	8,653	58.4% 9.6%
Total Technical Professionals[3]	167,434	22,816	21,240	23,650	41,743	109,449	69.1% 11.1%
TECHNICAL PARAPROFESSIONALS[2]							
Electronic Technicians	44,368	4,415	4,892	5,931	10,743	25,981	63.1% 10.3%
Assembly Personnel	110,892	11,385	14,031	15,497	24,329	65,242	63.7% 10.4%
Drafting Personnel	8,950	1,082	1,247	1,323	2,323	5,975	73.3% 11.6%
Other Paraprofessionals/ Technicians/Operators	38,537	3,242	2,989	3,434	6,861	16,526	46.5% 7.9%
Total Technical Paraprofessionals[3]	203,447	20,441	23,504	26,648	44,561	115,154	60.1% 9.9%
TOTAL ALL TECHNICAL CATEGORIES							
Total Technical Employees[3]	370,881	43,257	44,744	50,298	86,304	224,603	63.7% 10.4%
Number of Facilities Reporting	(815)	(815)	(799)	(773)	(745)		

[1] Technical Professionals: Those who hold jobs which require a bachelor's, master's, or doctoral degree or comparable experience.

[2] Technical Paraprofessionals/Technicians/Operators: Those who hold jobs which require one to two years of community college, vocational school, or on-the-job training.

[3] Totals listed in this row may be higher than the sum of.the figures for each specific job category, since some respondents could give projections only for total professionals and/or total paraprofessionals with job category breakouts.

[4] Simple Percentage of Growth gives overall increase from 1982 through 1987. It is adjusted for missing data.

[5] Annual compounded growth rate.

Selected Data

Projections for new job growth--both technical and non-technical--for all respondents is 49 percent over five years, or 8.3 percent ACGR. It predicts to be a healthy 11.1 percent for professionals and 10.4 percent for paraprofessionals annually through 1987 (Table 1).

The hot spots (i.e., over 100 percent) are computer/software engineers with 115 percent; computer analysts/programmers with 103 percent; and electronics engineering technologists with 107 percent (Figure 1).

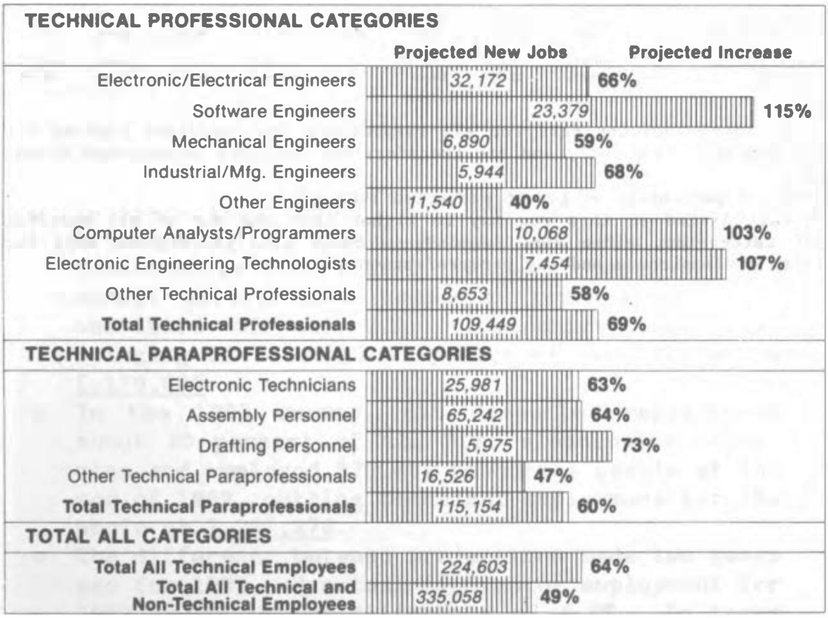

Figure 1. Projected United States job growth, 1983-1987 (815 facilities reporting).

TABLE 2. Total Projected Growth by Region and Job Category, 1983-1987

Technical Categories	Mid-Atlantic	Midwest	New England	Northwest	Southeast	Southwest	West (California)	Total U.S.[1]
Number of facilities reporting	(52)	(52)	(112)	(69)	(24)	(95)	(405)	(815)
Electronic/Electrical Engineers	3,002 48.3%[2]	2.002 58.6%	5,195 74.4%	1,416 88.1%	1,004 82.5%	4,872 63.0%	13,765 77.4%	32.172 65.5%
Software Engineers	2,156 106.6%	906 142.8%	4,291 122.8%	2,310 288.8%	1,043 106.5%	2,413 113.8%	9,700 114.3%	23,379 118.8%
Mechanical Engineers	377 18.8%	688 86.2%	1,079 127.8%	467 82.5%	163 84.0%	729 58.8%	3,102 61.6%	6,890 58.6%
Industrial/Manufacturing Engineers	298 34.2%	337 48.3%	722 91.6%	420 77.8%	192 63.0%	983 78.2%	2,912 78.2%	5.944 67.5%
Other Engineers	1,077 47.4%	254 48.5%	1,678 38.5%	416 47.2%	118 41.1%	977 78.2%	3,893 88.4%	11,540 48.0%
Computer Analysts/ Programmers	598 88.8%	411 81.5%	1,750 63.8%	469 127.4%	927 142.1%	1,802 142.7%	3,905 108.5%	10,068 102.5%
Electronic Engineering Technologists	1,023 91.5%	748 96.3%	760 72.1%	420 282.1%	608 162.6%	583 58.6%	3,166 136.3%	7,454 107.8%
Other Technical Professionals	1,083 44.8%	657 118.8%	1,975 88.2%	289 67.1%	59 50.4%	984 50.6%	2,918 63.0%	8,653 68.4%
Total All Technical Professionals[3]	9,610 81.6%	6,003 73.7%	17,450 74.8%	6,207 111.8%	6,202 88.2%	13,343 73.4%	43,862 88.8%	109,449 88.1%
Electronic Technicians	1,409 40.5%	1,460 63.0%	4,083 88.2%	1,281 42.4%	930 96.3%	3,224 40.8%	12,109 114.3%	25,961 88.1%
Assembly Personnel	2,881 33.9%	4,562 61.2%	9,570 57.8%	3,770 68.1%	2,314 67.0%	13,160 63.8%	26,877 108.7%	65,242 68.7%
Drafting Personnel	395 42.3%	387 68.1%	1,070 108.4%	433 61.4%	218 79.8%	872 72.7%	2,394 63.6%	5,975 73.3%
Other Paraprofessionals/ Technicians/Operators	2,381 78.6%	432 44.0%	1,838 78.3%	885 73.1%	284 66.0%	1,915 68.1%	4,992 61.0%	16,526 46.5%
Total All Technical Paraprofessionals[3]	7,068 40.5%	6,841 58.9%	16,561 96.3%	6,369 56.8%	4,381 77.1%	19,171 58.2%	47,167 50.4%	115,154 68.1%
Total All Technical Categories	16,676 40.5%	12,844 66.0%	34,011 88.8%	12,576 78.8%	10,583 82.1%	32,514 64.6%	91,029 88.4%	224,603 63.7%

[1] U.S. total includes data for six respondents that provided figures for the aggregate U.S. only and are therefore not included in regional breakouts.

[2] Overall percentage of growth projected 1983-1987.

[3] Totals listed in this row may be higher than the sum of all specific job categories, since some respondents could give projections only for total professionals and/ or paraprofessionals.

Regional comparisons of percentage growths (five-year totals) show the Northwest as highest for both electrical (86%) and computer engineers (268%); New England highest for mechanical (128%) and industrial/manufacturing engineers (92%); the Southwest highest for analysts/ programmers (143%); and the Northwest highest for electronics engineering technologists (262%). The Northwest leads with 111% growth in all technical professional jobs, followed by the Southeast with 86% (Table 2). The numbers in parentheses beneath each of the categories show the number of respondents in that particular region. This will give you a little bit of perspective of companies' views in both 1981 and 1983; and you can see that in all categories, except for computer engineers, their projections are down in 1983. The data was collected last year between February and March, when we were definitely in a recession.

Accuracy of Projections

It is premature to make judgments about the accuracy of these industry projections, especially since projections of any kind should be viewed only as trend indicators. However, comparisons of 1982 new-job projections made by AEA survey respondents two years ago with the numbers actually employed by the end of 1982 show remarkable concurrence in broad categories and in key ones such as electrical and computer engineering. Data extrapolations to the U.S. electronics industry as a whole provide the comparison basis:

- In AEA's 1981 report, 671 companies projected to have 389,073 technical paraprofessional and professional people by 1982. Based on employees and annual sales, these companies represented about one-third of all U.S. electronics companies, bringing 1982 technical personnel to a projected 1,179,000.
- In the 1983 survey, 815 companies represented about 30 percent of all U.S. electronics companies and employed 370,881 technical people at the end of 1982, putting technical employment for the whole at 1,236,270.
- The difference between projections made two years ago for 1982 and actual figures of employment for 1982 is 57,261--a difference of 4.8%. In terms

of overall technical employment, therefore, it appears respondents two years ago <u>underprojected</u> the actual trend by less than 5%.

- Looking solely at the category of technical professionals, it appears companies two years ago <u>overprojected</u> needs by 3.8%, or 22,500 employees. Within the technical professional ranks, the need for electrical engineers looks to have been <u>overprojected</u> by 5.1% and for computer engineers by 4.7%.

It is unclear whether overprojections represent miscalculations or indicate industry's inability to fill positions with qualified people. Based on the fact that the need for electronics engineering technologists was dra-

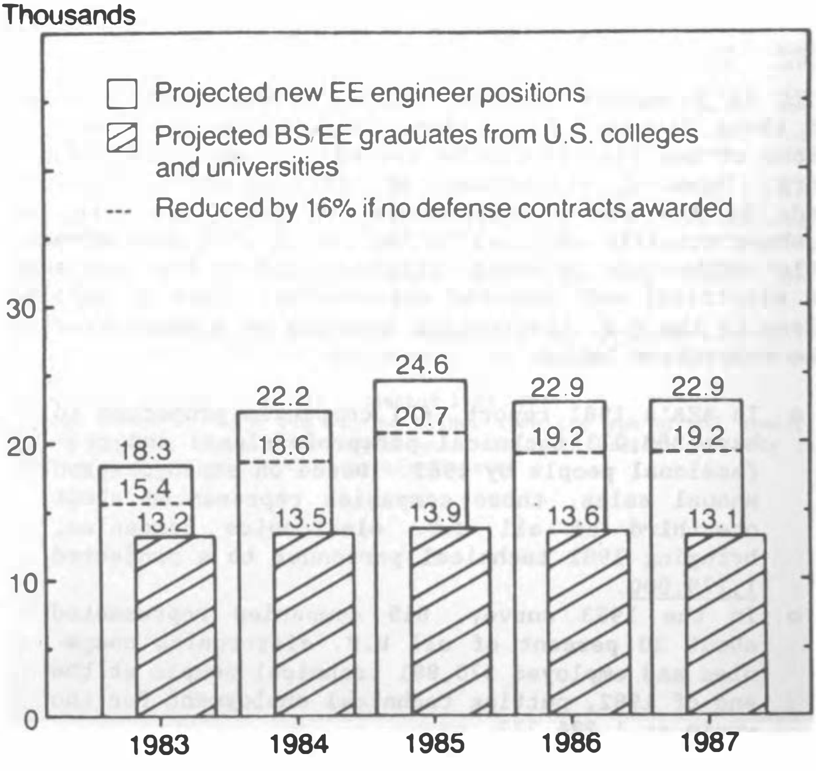

Figure 2. Electrical engineer supply and demand, 1983-1987.

matically underprojected by more than 50 percent two years ago, it is likely that technologists were hired to fill spots originally projected for electrical and computer engineers. In any case, a variation in key job categories of 5 percent or less between projected and actual is encouraging, if not conclusive.

Electrical and Computer Engineer Supply-Demand Imbalance

We extrapolated demand in two job categories only--electrical and computer engineering--assuming that AEA participants, based on annual sales and employees, represent 30 percent of the entire U.S. electronics industry. It is important to understand the assumptions behind the projections and the extrapolations.

Figure 2 juxtaposes projected industry demand against projected supply of new electrical engineering (EE) graduates with these assumptions:

1. EE demand is based on ACGR of 10.6%.
2. BS/EE graduate supply is based on National Center for Education Statistics' projections of a 2.4% annual growth through 1985 and a 2.5% decrease from 1985-1987. Supply projections are further reduced by almost 20%, since the National Science Foundation (NSF) estimates only 80.2% of all engineers are employed in U.S. industry.
3. Each year's shortfall may be reduced to eliminate duplicate defense contractor projections:

Year	Includes Defense Data	Excludes Defense Data
1983	5.1K	2.2K
1984	8.7K	5.1K
1985	10.7K	6.8K
1986	8.3K	5.6K
1987	9.8K	6.1K

Annual average shortfall each year, including defense data, is around 8,000; excluding defense data, around 5,000.

The projected need for EEs is 110,900, while the pro-

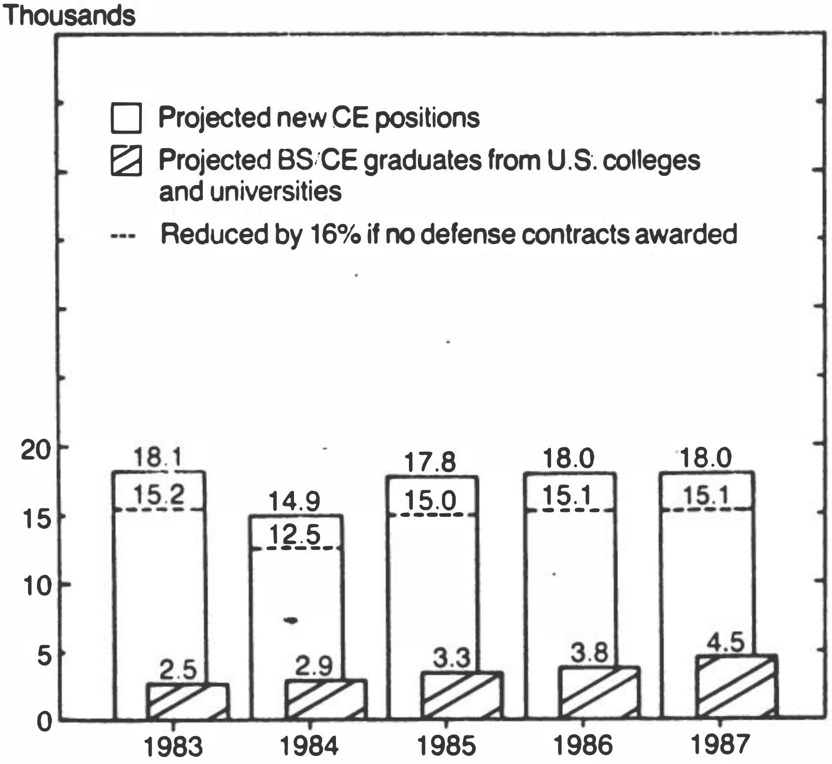

Figure 3. Computer engineer supply and demand.

jected number of new EE graduates is 67,296. This gives a projected shortfall of 43,604 electrical engineers (25,860 without defense).

Figure 3 juxtaposes projected industry demand against projected supply of new computer engineering (CE) graduates with these assumptions:

1. CE demand is based on ACGR of 16.5%.
2. BS/CE graduate supply is based on an annual growth of 15.8% (the average annual increase of computer engineering degrees awarded from 1977-1982). Projections assume that the number of BS/CE degrees will be awarded at the same rate as in the past five years. Supply projections are further reduced by almost 20%, since NSF estimates only 80.2% of all engineers are employed in U.S. industry.

3. Each year's shortfall may be reduced to eliminate duplicate defense contract projections:

Year	Includes Defense Data	Excludes Defense Data
1983	15.6K	12.7K
1984	12.0K	9.4K
1985	14.5K	11.7K
1986	14.2K	11.3K
1987	13.5K	10.6K

Annual average shortfall each year, including defense data is, around 14,000; excluding defense data round 11,000.

The projected need for CEs, 1983-1987, is 86,762, and the projected number of new CE graduates is 16,960--a projected shortfall of 55,920 (or 69,802 including defense).

The Electrical and Computer Engineer Shortage

Some suggest that the projected shortfall of electrical and computer engineers--which, by the way, is the only one that AEA ever made a statement on--is a result of weighted geography, a West Coast phenomenon caused by the high cost of living, which impacts out-of-state recruiting. The perspectives of the respondents, however, counter existence of this "weighting bias." Of the 406 respondents who reported some kind of electrical and computer engineer shortage, 55 percent viewed the major cause as "job growth exceeds supply." Twenty-eight percent viewed it as a result of "inadequate education and training" of applicants. Only 7 percent perceived "applicants unwilling to relocate" as a major reason, strongly suggesting that the shortage is not a recruitment problem unique to the West.

Colleges as Major Supplier

Participants indicate an intent to hire experienced engineers for two-thirds of their projected new jobs. Since the demand data reflects new job growth only, however, the supply will have to come primarily from new entrants into the labor market. Some may come from foreign countries, although respondents indicate an intent to hire only 1.1% (4,000 for the entire industry) from abroad. Some companies may hire less-qualified people and "make do"--clearly not a desirable option in this highly competitive, international market. Some job openings will undoubtedly be "backfilled" by professionals switching from one field to another; these individuals will likely go back to college for additional education or be trained in-house by a company. How extensive such backfilling is, as well as its impact on productivity and job performance, remains undocumented. It is, thus, fairly clear that most companies will have to seek new graduates as the primary source of new employees, especially if you keep in mind that these projections are only for employment within the high-technology industries. The capacity of U.S. engineering colleges is--as most of the country is now aware--impacted by a shortage of faculty, equipment, and facilities.

AEA Plan of Action

The survey data continues to stimulate pursuit of an active national program to assist engineering education. Since 1981 AEA has:

- Set a standard for each company to provide 2 percent of its R&D budget to engineering education. (Some $154 million has been tracked from AEA members to universities to date.)
- Established AEA industry committees to raise funds for engineering education and to work with state legislatures and universities to improve technical education budgets, faculty salaries, and programs. (Committees have been organized in Washington, Oregon, San Francisco, Los Angeles, Santa Barbara, Orange County, San Diego, Texas, Minnesota, and Massachusetts. To be formed in 1984 are New Jersey, New York, Connecticut, Arizona, Colorado, and Florida.)
- Established AEA's Electronics Education Foundation and raised $4 million, primarily in company support for U.S. citizens to get Ph.D.s and become engineering teachers and for faculty grants to help universities retain professors. (Some 32 companies are supporting 96 fellowships, 54 of these by HewlettPackard at a cost of $6 million.)
- Worked to enact state and federal legislation--primarily supporting that which encourages partnerships between industry, education, and government through tax incentives and other jointly

> leveraged measures that will communicate to the country that engineering education is in a state of great need and revitalization. (Key federal legislation is the "Scientific Research and Education Act"--S.2165 and HR.4475--designed to make the R&D tax credit permanent, enhance tax laws to encourage increased university research, and extend tax deductions under ERTA to include donations of teaching equipment, service and maintenance contracts, and software. Increased impact on the budget is intended to be offset by reductions brought about by the bill's tighter definition of R&D.)

Electronics ranks tenth among U.S. industry categories today and is expected to rank second by the end of the century. Export sales totaled over $25 billion in 1982. Electronics and information technology continually result in the creation of innovative and entrepreneurial new companies--a major source of economic growth in the U.S. economy. While high technology cannot be looked to provide <u>the</u> answer to the country's employment needs, it can be viewed as a major contributor through the creation of jobs within the industry itself, through the "job multiplier effect" in service and other economic sectors, and through the improvement of the productivity of American basic industries.

Reading through the reports of my colleagues on this panel, I did not see great disagreement. It seems to me that most of today's speakers recognize that electrical and computer engineering are two areas in which steady growth is projected. There also seems to be recognition by all on the panel that a shortage of faculty is impacting the production of supply. I suppose if I had to look at the differences between our views, I would say that I am not quite ready to accept the transportability from other professions into these job categories--i.e., people not educated in electrical or computer engineering and trying to turn them into those particular kinds of professionals. As high technology becomes increasingly specialized, this backfilling could have a severe effect on quality and productivity. It is an unclear area and could certainly be an agenda for the National Science Foundation, the National Academy of Engineering, and the National Research Council.

Technological leadership, a key national resource, is critical to the long-term growth of the country's domestic economy, to competitiveness in world markets, and to a strong national defense. This technological advantage, in the face of strong international challenges, will be maintained dependent on the availability of human resources. The AEA's effort in Technical Employment Projections contributes, hopefully, along with that of other organizations to helping to ensure that these technical professionals are available.

FUTURE LABOR-MARKET CONDITIONS FOR ENGINEERS

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Bureau of Labor Statistics

Introduction

My remarks today will focus on the Bureau's method of projecting employment and supply-demand conditions and our recently released 1995 projections. I will do this, of course, with reference to engineers. First, however, I would like to discuss briefly the meaning of the term "shortage", because we are really here today to discuss different views of whether there is a current and a prospective shortage of engineers.

The term "shortage" is often given different meanings by employers, by groups of workers, and by others concerned with market conditions in a specific occupation. In traditional economic terms, a shortage is a disequilibrium condition in the job market in which employer's demand for workers with a specific education/training mix exceeds the number available and willing to work at the existing wage and other working conditions. Employers may respond to a real or perceived shortage in an occupation by raising wages, intensifying recruiting, or broadening hiring standards (such as a willingness to accept recruits with lower grades, or with degrees in other fields, or experienced workers who may need additional orientation or some retraining). These actions are designed to increase supply--because individuals should respond to higher relative wages and seek jobs in the occupation or training to qualify for the occupation and because the available pool will be expanded with reduced standards. Employers also may reduce demand for engineers by substituting capital for labor or substituting other occupational skills (such as technical for engineering), thereby changing the manner in which goods or services are produced.

While some supply responses to employer actions can occur in a short time-frame, others--particularly increases in the supply of new graduates--need a longer period of time. If short-run responses are not adequate, shortages can persist in some occupations even when these market forces come into play. Also, some employers may have constraints in their ability to raise salaries or reduce standards. For example, universities with Ph.D. requirements and uniform salary scales for all fields or government agencies with rigid civil service pay scales and hiring specifications cannot adjust--at least in the short run--and may have unfilled jobs while the market clears for other employers who have adjusted to market conditions.

Even if market adjustments do bring about a balance between supply and demand, the consequences of the process can cause concern not only to employers but also among the general public. Broader hiring standards and reorganized production methods could result in production delays, lower quality goods and services, lower productivity, or higher costs. Since these are not desirable from a public policy standpoint, shortages are a concern of the government. This is especially true for engineers, since it is commonly accepted that the services of engineers are vital to a strong economy, increasing productivity, technological leadership, and national defense.

There are differences of opinion concerning the existence of current and potential future shortages of engineers. Even those who believe shortages exist differ in their views of the severity of the situation. In describing BLS's view as it stems from our recent projections, I would first, however, like to describe the methods used by BLS to project employment and analyze future supply-demand conditions.

BLS Projection Procedures

The Bureau of Labor Statistics prepares projections on a two-year cycle, using the Economic Growth Model System.[1] This system is composed of a group of separate but

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[1] See BLS Economic Growth Model System Used for Projections to 1990, Bulletin 2112, for more details of each step in the procedure discussed in this paper.

not unrelated processes. Projections are produced in the following areas: (1) labor force; (2) aggregate economic performance; (3) industry final demand and total industry production; (4) industry employment levels; and (5) occupational employment by industry. Each block of the projections depends upon inputs from an earlier stage and feeds logically into the next.

The labor force projections use the Bureau of the Census population projections by age, sex, and race, based on trends in birth rates, death rates, and net migration. With the population projections in hand, BLS projects labor force participation rates--the percent of each group in the population who will be working or seeking work--for 64 age, sex, and race groups. The labor force participation rate projection for each group is developed by analyzing past rates of change. If past trends are judged not likely to continue throughout the entire projection period, the rate is modified. The levels of anticipated labor force are calculated by applying the projected participation rates to the Bureau of the Census population projections.

The aggregate economic projections (Gross National Product), in total and by major demand and income category, use the BLS labor force and Census population projections as inputs. Consistent economic scenarios are developed to provide aggregate controls for the various categories of demand and employment. These scenarios are selected to encompass a band around likely growth of the economy in the future. Later stages of the projection process develop industry-level projections consistent with these aggregate data.

The Bureau's aggregate economic projections are developed based on a macro model developed by Chase Econometrics Associates, Inc. That quarterly model of the U.S. economy, is composed of 312 behavioral equations and 275 identities, thus determining 587 endogenous variables. In addition, the model contains 110 exogenous variables. Assumptions are specified for the 110 exogenous variables, and the model is simulated. The results are analyzed for consistency and reasonableness, and modifications to the exogenous variables and to the behavioral relationships are incorporated into the model until a reasonable set of results has been obtained.

For the industry output projections, the U.S. economy is disaggregated to 156 producing sectors, an exhaustive grouping that combines both the public and private sectors. The framework for this procedure is an input-output model prepared for a base period by the Bureau of Economic Analysis of the U.S. Department of Commerce. The first step at the industry level is to disaggregate the GNP estimate from the aggregate projections to a set of demands by industry. This projected industry demand, in conjunction with a projected input-output table, is used to calculate total industrial production. The projected changes in input-output coefficients in the input-output model capture, among other factors, expected changes in technology. Finally, the employment necessary to produce those levels of output is estimated through use of projected industry productivity.

Aggregate demand projections are available from the macro model for fifteen categories of consumption, eight types of investment, fifteen end-use categories of foreign trade, and three categories of government spending. Where possible, a further disaggregation of the control values is undertaken: purchases of producers' durable equipment is divided into 23 types of capital equipment. Government spending is grouped into 12 categories.

To allow for shifts in the composition of aggregate demand and in the industrial makeup of a given demand category, "bridge tables" are projected. The bridge table is a set of percent distributions for each given demand category, such as one of the consumption groups or investment, among each of the 156 industries in the BLS input-output model.

The projection of the input-output table accounts for the changes in the input patterns for each industry. In general, two types of changes are made: (a) those made to the inputs of a specific industry after an industry study (as, for example, the changes in inputs in the aluminum industry) and (b) those made to the inputs of all industries for a specific commodity (as, for example, increased use of business services across a wide spectrum of industries). Output requirements by industry are the result of multiplying the projected input-output table by projected changes in the level and distribution of final demand.

The projected changes in industry output are important factors determining the projections of industry employment. However, converting output projections into employment estimates requires productivity-industry projections and measures of changes in average hours by industry. This is accomplished by using a regression model, with an equation for each industry, that estimates worker hours as a function of the following variables:

(1) the industry's output, (2) capacity utilization, (3) the relative price of labor, and (4) a technology variable as approximated by the output/capital ratio. Worker hours are converted into jobs by dividing by average annual hours, which are projected using time trends. The sum of employment by industry is controlled to total employment as estimated in the macro model. Several iterations are usually necessary for a reasonable balance to be achieved.

Projections of employment for the 156 sectors in the Economic Growth Model are disaggregated to 372 industries corresponding to the three-digit Standard Industrial Classification (SIC). This is done to match the industry detail of the industry-occupation matrix described later. The disaggregation is accomplished via a time-series regression model. The disaggregated three-digit SIC industry employment projections are reviewed in light of a broad range of economic information. When the industry projections are considered final, they are used as inputs to the process of projecting occupational employment.

The main resource used to develop occupational employment projections is the industry-occupation matrix. This matrix is produced from data collected by State Employment Security Agencies and brought together by the Bureau of Labor Statistics to produce national estimates. The data are collected from employers on a three-year cycle--manufacturing one year, nonmanufacturing the next year, and the balance of nonmanufacturing (trade, transportation, communications, and utilities) the final year. The data from the three-year cycle are put on the same employment basis (the base year of the projections) to form annual average estimates for occupational employment in each of the three-digit SIC industries. The matrix contains over 1,500 detailed occupations, although most industries do not have employment in many of these occupations.

The occupational cells of the industry-occupation matrix for the base year are analyzed and projected to account for changes expected to take place in the industries because of technological change, product mix shifts, and other factors. The changes introduced into the input-output model for expected technological change may also change the staffing patterns in industries using the new technology (for example, one would expect more employment of computer specialists as computer technology spreads across industries). The projected industry employment data are applied to the projected industry occupational employment patterns; and for each occupation employment is aggregated across all industries to yield total occupational employment for the projected year.

Using these procedures we have developed estimates of employment for all occupations--including engineers--for a low-, a moderate-, and a high-growth scenario to 1995. These projections represent only three of many possible responses of the economy to differing fiscal and monetary stimuli. A different perspective on the inner workings of the U.S. aggregate economy could easily lead one to arrive at different results. It is possible to envision a scenario generating much lower engineer employment. One much higher, however, does not seem likely.

I'll concentrate my remarks primarily on the moderate scenario. While some of the macro assumptions are fairly optimistic, in many occupations our analyses have shown that the growth of individual occupations may not be that sensitive to changes in macro assumptions. Among the specific assumptions made are unemployment declining to 6 percent by 1995 and GNP growth averaging about 3 percent over the period--somewhat faster than since 1973, but slower than during the 1960s. Defense spending, on the other hand, with its high engineering-employment impact, is projected to grow sharply through 1986 and then increase more slowly thereafter; the 1995 level is projected to be about 40 percent above the 1982 level in real terms.

Growth of Engineers

In the moderate growth scenario, we project a growth in engineering employment of 48 percent over the 1982-1995 period--a net increase of 585,000 jobs, or about 45,000 a year, on average. About two-thirds will be due to growth in industries in which engineers are employed and one-third due to the relative increase in the use of engineers in individual industries. Engineers have been growing faster than total employment in most industries during the past five or six years. This trend is projected to continue, but at a slower rate.

Growth is projected for all branches of engineering, with electrical engineers projected to grow fastest, 65 percent. Although making up 27 percent of all engineers in 1982, they constitute 35 percent of growth. Projected growth is broad-based across industries (Table 1). About 20 percent of the 585,000 growth in engineering employ-

TABLE 1. Projected Growth in Engineering Employment, 1982-1995, by Selected Industries

			1982-1995		
Industry	1982	1995	Growth	%, All Growth	Growth Rate
Total	1,204.3	1,788.4	584.1	100.0	48.5
Mining	36.5	43.5	7.0	1.2	19.2
Construction	47.1	74.4	27.3	4.7	58.0
Manufacturing	588.1	864.9	276.8	47.4	47.0
Durable goods	500.8	757.7	256.9	44.0	51.1
Machinery, ex. electrical	121.8	206.0	84.2	14.4	69.1
Office, computing and accounting	58.2	102.5	44.3	7.6	76.1
Electrical machinery	152.3	235.4	83.1	14.2	54.6
Communication equipment	77.3	102.7	25.4	4.4	32.8
Electronic components	40.8	85.1	44.3	7.6	108.5
Transportation equipment	129.4	177.8	48.4	8.3	37.4
Aircrafts and parts	66.8	92.1	25.3	4.3	37.9
Nondurable goods	87.3	107.3	20.0	3.4	22.9
Transportation, communications and utilities	81.3	127.8	46.5	8.0	57.2
Communications	41.1	75.9	34.8	6.0	84.7
Wholesale and retail trade	45.5	57.5	12.0	2.1	26.4
Services	211.7	401.6	189.9	32.5	89.7
Business services	61.8	131.1	69.5	11.9	112.1
Engineering, architectural and surveying services	121.7	235.3	113.6	19.5	93.3
Government	148.2	169.9	21.7	3.7	14.6
Federal	87.0	106.1	19.1	3.3	21.9
State	32.3	31.5	-0.8	--	-2.5
Local	28.9	32.3	3.4	0.6	11.8

Note: Based on moderate-trend scenario.

ment projected is in engineering and architectural services, the largest employer of engineers in 1982. Engineering employment in this industry, is projected to grow 93 percent. Other industries with large growth are electronic components manufacturing (which is projected to grow 109 percent and to require about 45,000 new jobs) and office, computing, and accounting machines (which is projected to grow 73 percent and also to require 45,000 new jobs).

Our high-growth model would generate about 4,000 more openings a year. The low-growth scenario shows the same 1995 employment as the moderate-growth scenario. Higher defense-related employment in the low model compensates for lower employment in other industries.

Separations

Growth of an occupation only determines part of total openings. In most occupations the need to replace workers who leave the occupation is an even greater source of openings. Based on an analysis of mobility data for 1980, we estimate that engineers left the occupation at an annual rate of 6.25 percent; most transferred to other occupations. Limited data indicate movements to management or management-related jobs, other technical jobs including technical sales, and a wide range of other occupations. Earlier studies by BLS and the National Science Foundation indicate similar separation rates over the past two decades. This rate is also close to that observed for other predominantly salaried professional occupations such as accountant and chemist. Indications are that many individuals who transfer out of engineering eventually return to engineering and thereby become part of the supply. Unfortunately, detailed data on this exit and return phenomenon are not available.

Applying this 6.25 percent separation rate to projected average employment over the period yields 93,500 openings annually. Adding 45,000 openings calculated for growth yields 138,500 openings annually, on average.

Available New Graduates

The National Center for Education Statistics (NCES) projects total bachelor's degrees but no longer makes projections by field. NCES data indicate that about

80,000 bachelor's degrees in engineering and engineering technology were granted in 1982, accounting for 8.4 percent of all bachelor's degrees granted. By assuming that engineering degrees will remain at this percent of total degrees through 1995 and using NCES intermediate projections of total bachelor's degrees, we get an annual average of 79,000 engineering degrees for the 1982-1995 period. The numbers increase for several more years but then begin a moderate decline in 1986, reflecting the declining college age population. Of course, the proportion studying engineering could decline sharply in response to engineer layoffs, as it did in 1970 and 1971; but as long as the demand for engineers remains as strong as we are projecting, the proportion is not likely to drop. The absolute number is not likely to rise very much, given the shortage of engineering faculty, but it is possible that the number will not decline after 1986. It should be kept in mind that these degree projections are done independent of demand (other methods of projecting engineering degrees have been developed that assume an interaction between supply and demand).

In the past about 80 percent of engineering graduates have entered engineering, and we have assumed that this proportion will remain unchanged through the mid-1990s. Adjusting the number of degrees by this factor yields an annual average estimate of 63,200 entrants with engineering degrees. This number is 46 percent of the projected number of openings calculated earlier.

This 46 percent ratio of recent graduate entrants to total openings does not imply a shortage of 54 percent of demand. In 1980, the most recent year for which we have reasonably comprehensive data on total entrants to engineering, we estimate that about the same proportion of all entrants were recent engineering graduates. Others came from a wide range of sources, such as: (1) transfers from other occupations, (2) employed people with previous experience or training in engineering or a related occupation, (3) recent science and math graduates, (4) immigrant engineers, and (5) older engineers returning to the occupation. Thus, we anticipate that the availability of recent engineering graduates relative to total openings will be roughly the same as in 1980.

Market Conditions

One good measure of market conditions is changes in the salaries of engineers relative to those of other workers, since (as I discussed earlier) employers are inclined to bid up salaries when they experience shortages. BLS data indicate that, since the early 1970s, engineers' starting salaries have increased relative to other professional workers and men with four or more years of college. Salaries of experienced engineers, however, have not changed relative to others since the early 1970s, or even the early 1960s. Another measure of market conditions is the unemployment rate. In 1980 the unemployment rate for engineers was 1.3 percent. This rate was below the high of 2.9 percent in 1971, right after major layoffs; but it was above the 0.7 percent rate of the late 1960s, when there were numerous reports of shortages. In general, these data indicate that recent graduates may have been in short supply, to a limited extent, but that overall, no significant problem existed. This conclusion is also consistent with anecdotal evidence that shortages existed in some specialties, but that overall, shortages were not a significant constraint on engineering activities.

In summary, the availability of new engineering graduates relative to total openings is projected to be roughly the same as in recent years, when there was no overwhelming indication that significant shortages existed. Assuming a similar availability of other entrants, significant shortages would not be expected during the next 13 years; and there would, therefore, be no need for employers to broaden hiring standards significantly, bid up relative wages, delay productions, or make other adjustments.

Short-Run Imbalances

Even though the BLS analysis indicates a rough overall balance between requirements and supply, imbalances over short periods of time and among specialties are inevitable, given the nature of the engineering labor market. Most engineers are directly or indirectly involved in producing either goods such as industrial machinery and other producer durables or buildings, factories, and other structures--products for which demand fluctuates widely over the business cycle. Another large group of engineers is involved with producing military hardware or doing related R&D. Defense spending has fluctuated widely, directly affecting the demand for engineers, and may continue to do so over the long run, even though in the short run it is expected to increase.

Engineering has a great many subdivisions and specializations. An engineer's experience is often limited to one or a few specializations; and employers, when seeking experienced engineers, often have narrow hiring specifications. Therefore, mobility between specializations to bring about adjustments in supply and demand is impeded. In addition, recent graduates and older engineers in the same speciality often are considered to have different skills and may be considered by employers to have limited substitutability.

Selected areas of engineering are characterized by rapidly changing technologies. In these areas, there very likely will not be sufficient engineers with formal training or experience, particularly those dealing with the cutting edge of that changing technology. However, it is unrealistic to expect that the educational system will or can anticipate needs in fields where a technology may not yet exist or is only in the early stages of development. Therefore, needs have to be met by training engineers from related specializations. Such conditions have always existed; and despite them, employers have generally been able to accomplish engineering goals. This is very likely to be the case in the future.

It is apparent that I have addressed the issue of shortages from a standpoint of the availability of workers to fill available jobs. The scenario I have described, which indicates a rough supply-demand balance, does not deal fully with quality. If reductions in quality of our nation's engineers has already taken place, the situation may not improve in the future. Our data sources do not allow for this analysis. It is, however, an important topic and perhaps the most significant point in discussion of the adequacy of engineering supply.

Perhaps it is best to end a discussion of the future by noting some of the uncertainties that may have a significant bearing on what actually will happen to the demand, supply, and supply-demand conditions for engineers through the mid-1990s. I will discuss them as they relate to the Bureau's analysis, but keep in mind that these same uncertainties also have a significant bearing on analyses done by others. First, our demand projections are based on significant increases and continued high levels of defense expenditures. A different political climate at some period between now and 1995 could result in a significant decline in defense spending, which would reduce engineering employment significantly. We all remember 1970. In addition, we have assumed that engineering degrees will account for the same proportion of total degrees over the 1982-1995 period as they did in 1982. This proportion could increase. With a decline in total degrees awarded in the latter part of the projection period because of the decline in the college-age population, the proportion of total degrees in engineering could increase if there is only a small or moderate increase in the capacity of engineering schools. This would increase the supply of new graduates above the levels that we have projected.

Both of the uncertainties I have just described would tend to reduce or alleviate any shortage condition. However, it is also possible that employers may feel that they cannot continue to broaden hiring standards to the extent they have in the past. They could require a higher proportion of total entrants to have engineering degrees, or they could leave positions unfilled. This would, of course, tend to exacerbate shortage conditions. There are many other uncertainties. Perhaps the only thing certain about the future job market for engineers is that at this time it is uncertain what the exact supply-demand conditions will be in the 1990s.

PROJECTED LABOR-MARKET BALANCE IN ENGINEERING AND COMPUTER SPECIALTY OCCUPATIONS: 1982-1987[1]

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Introduction

The labor market for highly trained science and engineering (S/E) personnel generally responds to industrial growth and economic activity with a lag. Thus, as a result of weak performance at the beginning of the '80s, labor market analysts and industrial employers are expressing little concern over general personnel shortages in these occupations. Those concerns that do exist are relegated to specialized areas of the labor market. These include electrical/electronic engineering and computer-related occupations that are expected to resume their strong employment growth, as well as new occupations that are being required by emerging technologies.[2] If one wanted to search below the surface, one could also point to problems related to the competition between aca-

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[1] This paper is based on a National Science Foundation (NSF) analysis of the projected impact of the defense buildup on the science, engineering, and technician (SET) labor market. (National Science Foundation, "Projected Employment Scenarios Show Possible Shortages in Some Engineering and Computer Specialities," Science Resources Studies Highlights, NSF 83-307, and Projected Response of the Science, Engineering, and Technician Labor Market to Defense and Nondefense Needs, 1982-87, Special Report, Washington, D.C., forthcoming.)

[2] National Science Foundation, "Industry Reports Shortages of Scientists and Engineers Down Substantially from 1982 to 1983," Science Resources Studies Highlights (NSF 84-303), Washington, D.C., January 1984.

demia and industry for qualified engineering and computer personnel, as well as to industrial concerns about the availability of appropriately trained, experienced workers.

A number of factors can be expected to have a significant impact on the S/E labor market during the next several years. Large increases in requirements can be expected to result from the defense buildup. As depicted in the five-year defense plans proposed by the Administration throughout the early '80s, this buildup represents the largest planned increase in such spending during peacetime and is directly targeted on S/E-intensive high-technology procurements and research and development activities. Defense demands, moreover, will have to compete within the context of growing nondefense requirements. The strong economic recovery that began in 1983 will provide a solid basis for future employment growth in S/E occupations. Beyond general employment expansion, however, will be the increased requirements generated by shifting industrial composition toward high-technology industries and by industrial staffing changes that favor the utilization of S/E personnel relative to workers in other occupations.[3] Because rapid employment growth can strain available labor supply in highly specialized fields, in 1982 the National Science Foundation undertook an analysis of potential labor market balance in science, engineering, and technician occupations for the five-year period ending in 1987. This paper will concentrate on those findings related to labor-market conditions within engineering and computer-related occupations.

Methodology

This analysis utilizes two state-of-the-art projection models. Requirements are estimated using a dynamic input/output (I/O) model, the Defense Interindustry Forecasting System developed by Data Resources, Incorporated

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[3] National Science Foundation, Changing Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries: 1977-80, Final Report (NSF 83-331), Washington, D.C., October 1982.

(DRI).[4] Because projections are highly dependent on the assumptions underlying them, four scenarios were run to provide a well-defined range within which employment is likely to occur (Table 1). These scenarios were based on varying assumptions about general performance of the U.S. economy and the level and distribution of defense expenditures. Variations in macroeconomic activity were based on high (OPTIM) and low (STAG) economic-growth assumptions. In the OPTIM scenarios, the first half of the simulation period is characterized by a vigorous economic recovery that moderates to a long-run growth path in subsequent years. In the STAG scenarios, poor economic performance persists until mid-decade, after which time moderate economic growth occurs. Variations in defense expenditures assume either full implementation of the Administration's FY 1983 Five-Year Defense Plan, with real spending increasing at an average annual rate of 8 percent over the projection period, or a more moderate plan characterized by a 3-percent real annual rate of increase. These defense spending assumptions are indicated by the titles HIGH and LOW, respectively.

Labor market balance is determined by comparing estimates of labor demand with those of available supply. The most distinguishing feature of this analysis is the use of a model that depicts operations of the entire science and engineering (S/E) supply system as it responds to changing job opportunities. Developed under contract to NSF by Drs. Robert Dauffenbach, Jack Fiorito, and Hugh Folk, the model determines the supply of personnel in any given year from supply in the preceding year adjusted to account for the net effect of worker flows into and out of various occupations.[5]

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[4] The DIFS model is a commercial version of the Defense Economic Impact Modeling System (DEIMS), a collaborative effort of DRI and the Department of Defense (Department of Defense, Office of the Secretary of Defense, Defense Economic Impact Modeling System, Washington, D.C., July 1982.)

[5] Robert C. DauffenBach and Jack Fiorito, Projections of Supply of Scientists and Engineers to Meet Defense and Nondefense Requirements, 1981-87: A Report to the National Science Foundation, NSF Contract No. SRS-8210548, Oklahoma State University, Stillwater, April 1983.

TABLE 1. Summary Statistics for Macroeconomic/Defense Expenditure Scenarios, 1983-1987*

Macroeconomic Indicators	STAG/ LOW	STAG/ HIGH	OPTIM/ LOW	OPTIM/ HIGH
Average annual rates of change:				
Defense expenditures, constant $	3.1	8.1	3.1	8.1
Gross national product, constant $	1.6	2.2	3.5	4.3
Industrial production	2.2	3.0	5.3	6.4
Consumer price index	7.2	7.4	6.1	6.4
Average annual unemployment rate	10.5	9.8	7.3	6.6

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

SOURCE: National Science Foundation.

Personnel flows in the model relate to three types of workers: new labor force entrants, experienced workers, and immigrants. New entrants become part of available 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 are modeled to influence the supply behavior of these workers including demographic trends, family income, labor-market conditions, and the compatibility of college coursework and occupational skill requirements. Experienced workers provide a short-term flexibility to the S/E supply system that cannot be met through recent college graduates. The experienced work force is incorporated into the supply model through estimates of personnel flows into, among, and out of S/E occupations, as well as flows out of the labor force that result from deaths and retirements. Experienced worker behavior is primarily determined by job opportunities, as well as occupation-specific characteristics. The supply behavior of immigrants is affected by labor-market conditions and immigration laws.

Projected Requirements in Engineering and Computer-Related Occupations

Because engineering and computer specialty occupations are concentrated in high-technology industries, they are particularly sensitive to the industrial pattern of economic growth and the level and distribution of defense expenditures. Nonetheless, the four scenarios that form the basis of this analysis indicate a relatively narrow range of projected employment. The STAG/LOW and OPTIM/HIGH scenarios, which define the maximum variation in demand, project 1987 engineering employment to range from 1,300,000 to 1,420,000, implying a net addition of 160,000 to 285,000 jobs over the 1982-1987 analysis period (Figure 1). For computer specialty occupations, employment is expected to range from 577,000 to 603,000 in 1987, a net increase of 125,000 to 150,000 jobs (Figure 2).

Overall, the projections suggest an easing of the employment growth in engineering and computer specialty occupations that was observed in the five years preceding 1982 (Table 2). The annual rate of engineering employment growth, projected to range from 2.6 percent to 4.5 percent between 1982 and 1987, lies below the 4.7 percent

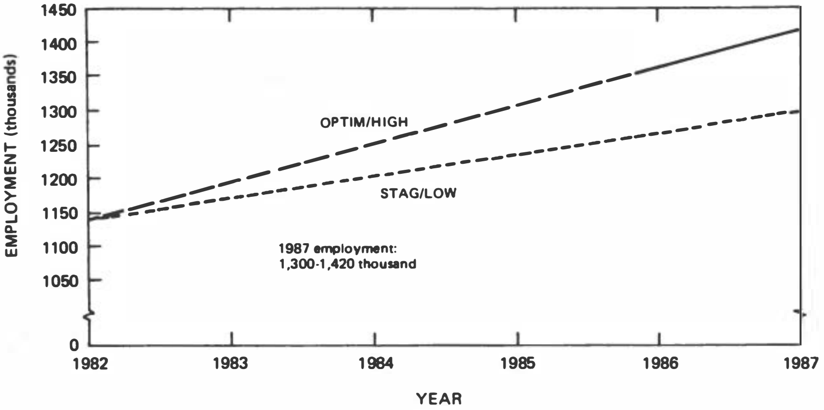

Figure 1. Projected range of employment in engineering occupations.

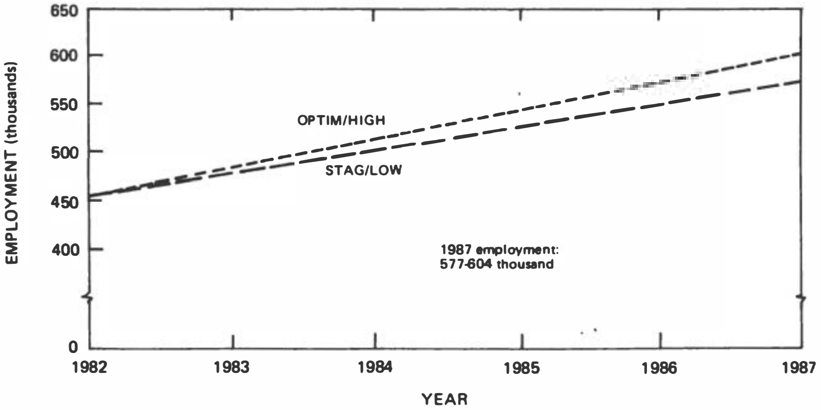

Figure 2. Projected range of employment in computer specialty occupations, including both computer systems analysts and programmers.

TABLE 2: Projected Requirements in Engineering and Computer Specialty Occupations (in thousands)

	Projected Employment*					
	STAG/LOW			OPTIM/HIGH		
Occupation	1982 employment	1987 employment	Annual growth rate 1982-1987	1987 employment	Annual growth rate 1982-1987	Annual growth rate ** 1977-1982
Total engineers	1,139	1,296	2.6%	1,423	4.5%	4.7%
Aeronautical/astronautical	64	86	5.9	109	11.1	5.6
Chemical	53	57	1.6	61	2.7	6.2
Civil	163	175	1.3	189	2.9	3.4
Electrical/electronic	327	396	3.9	421	5.1	4.1
Industrial	109	120	2.0	131	3.6	5.1
Mechanical	202	224	2.1	248	4.1	2.0
Metallurgical	15	16	1.9	18	4.4	1.2
Mining/petroleum	28	32	2.8	32	2.7	7.4
Engineers, n.e.c.	177	190	1.4	214	3.8	8.1
Total computer specialists	454	577	4.9	603	5.8	13.8
Systems analysts	219	287	5.6	303	6.7	14.4
Programmers	235	290	4.3	300	5.0	13.3

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

** Based on Bureau of Labor Statistics' Current Population Survey (CPS).

SOURCE: National Science Foundation.

annual growth experienced from 1977 to 1982; the 4.9-5.8 percent annual employment growth in computer specialty fields lies well below the 13.8 percent growth experienced during the earlier period. Cursory analysis, therefore, suggests that the labor market in these occupations could probably accommodate the projected increase in personnel requirements. Problems, should they occur, would most likely arise in those occupations for which there is an indication of accelerated employment demand --namely, aeronautical/astronautical, electrical/electronics, mechanical, and metallurgical engineering.

Assessment of Labor-Market Balance

Alternative Analyses of Supply

Supply response restricted to new entrants and immigrants. Potential labor-market imbalance is most frequently analyzed at the margin--i.e., for any given time period, an assessment is made as to whether the numbers of new S/E graduates and immigrants are 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.[6] The set of supply-model simulations replicating this form of analysis provides worst-case estimates of labor shortages and is used to identify those occupations most prone to labor-market imbalance.

Supply response including mobility. It is unlikely that personnel shortages will be reflected as unfilled job vacancies to the extent anticipated when supply adjustments are restricted to new entrants and immigrants. La-

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[6] More recent training in basic principles may make new entrants more fungible, giving the employer an opportunity to train a given job applicant in fields outside his/her discipline of study. The occupational choice subcomponent of the supply model permits such field switching.

bor markets do not tolerate prolonged imbalances and will almost immediately begin to equilibrate the demand and supply of personnel.[7] Increasing job opportunities coupled with the incentives of rising wages and improved benefits can be expected to entice workers into occupations experiencing personnel shortages. College students may be drawn into the work force, foregoing further training; technicians may assume responsibilities usually carried out by more highly skilled personnel; and workers may decide to enter those occupations most in demand even if their training and job experience are in other fields. The latter two types of adjustments are critical in determining the ability of the work force to meet short-term growth requirements. To assess the full range of labor-market dynamics, the supply system was simulated a second time, allowing variations in personnel supply to be derived from new labor force entrants, immigrants, and net transfers from other occupations.

Projections of General Labor-Market Balance, 1987

Two concepts of labor-market shortage are used in this analysis, corresponding to the alternative sets of supply simulations. The first deals with personnel shortages as derived from the "worst-case" supply scenarios. In this analysis, several assumptions are made about the degree of imbalance the labor market can support before problems develop. The first assumption is that projected supply shortfalls of up to 5 percent are sufficiently small so that market adjustments could easily accommodate them. Occupations in which projected supply falls short of demand by more than 5 percent are considered to be of 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.

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

Despite the forced inflexibility of labor supply in the "worst-case" supply scenarios, the overall number of engineering personnel is projected to be more than adequate to meet the demands created by employment growth and the replacement needs resulting from deaths and retirements. General labor-market balance, however, does mask potential problems for some engineering specialties, with shortages indicated for aeronautical/astronautical and electrical/electronics engineering occupations. A large personnel shortage is also projected for computer specialty fields (Table 3). Among the remaining engineering specialties, industrial and mechanical engineering appear to be in rough balance; all other fields are projected to have personnel surpluses.

A second concept of personnel shortage, work force quality, is used to analyze results from the version of the model depicting the full supply system, which includes market-sensitive, occupational mobility. With such mobility taken into account, no single occupation is characterized by market imbalance under the criteria set previously. Supply adjustments elicited to meet growing requirements, however, suggest a problem seldom considered explicitly in studies of labor-market balance. That problem is whether large market adjustments can be sustained while fully meeting the quality requirements for specialized personnel. Given the high skill content of engineering and computer-related jobs, the pool of similarly trained people in related fields is likely to be limited. Once this source is exhausted, the available pool of entrants may not have essential skill requirements unless a significant amount of training is provided. 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."[8] 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 such criteria are met, the general quality of the work force will be diminished. Use of inadequately trained workers is, in itself, a manifestation of labor-market shortage.

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[8] DauffenBach and Fiorito, op. cit.

TABLE 3. Projected Labor-Market Balance in Engineering and Computer Specialty Occupations (New Entrants and Immigrants), 1987

Occupation	Sufficient supply (No shortage)	Insufficient supply[2] High rate of inmobility (Shortage)	Insufficient supply[2] Low to moderate rate of inmobility (Potential shortage)
Engineers			
Aeronautical/astronautical		*,+	
Chemical	*,+		
Civil	*,+		
Electrical/electronics	*		+
Industrial	*,+		
Mechanical	*,+		
Metallurgical	*,+		
Mining/petroleum	*,+		
Engineers, n.e.c.	*,+		
Computer specialists[1]		*,+	

[1] Includes both computer systems analysts and programmers.

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

NOTE: 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.

Table 4: Projected Labor-Market Balance in Engineering and Computer Specialty Occupations, 1987

		New Entrants and Immigrants[1]			New Entrants, Immigrants, and Occupational Mobility[2]		
Occupation	Requirements	Total supply	Balance surplus(+)/ shortage(-)	Balance surplus(+)/ supply	Total supply	Balance surplus(+)/ shortage(-)	Balance as percent of supply
				STAG/LOW			
Total engineers	1,296	1,495	198	13	1,319	23	2
Aeronautical/astronautical	86	73	-13	-18	84	-2	-2
Chemical	57	88	30	34	61	3	5
Civil	175	216	42	19	177	2	1
Electrical/electronics	396	387	-9	-2	398	2	0
Industrial	120	129	9	7	120	0	0
Mechanical	224	267	43	16	230	7	3
Metallurgical	16	23	7	30	17	1	6
Mining/petroleum	32	36	4	12	33	1	3
Engineers, n.e.c.	190	275	85	31	199	9	5
Computer specialists	577	462	-115	-25	568	-9	-2
				OPTIM/HIGH			
Total engineers	1,423	1,598	84	6	1,437	14	1
Aeronautical/astronautical	109	74	-35	-47	105	-4	-4
Chemical	61	88	27	31	64	3	5
Civil	189	218	29	13	190	1	1
Electrical/electronics	421	390	-31	-8	421	1	0
Industrial	131	130	-1	-1	130	-1	-1
Mechanical	248	270	22	8	253	5	2
Metallurgical	18	23	5	22	19	1	5
Mining/petroleum	32	36	4	11	32	1	3
Engineers, n.e.c.	214	279	64	23	222	8	4
Computer specialists	603	466	-138	-30	593	-11	-2

[1] Supply: Adjustments based on new entrants and immigrants.
[2] Supply: Adjustments based on new entrants, immigrants, and occupational mobility.

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

Projected Shortage Fields, 1987

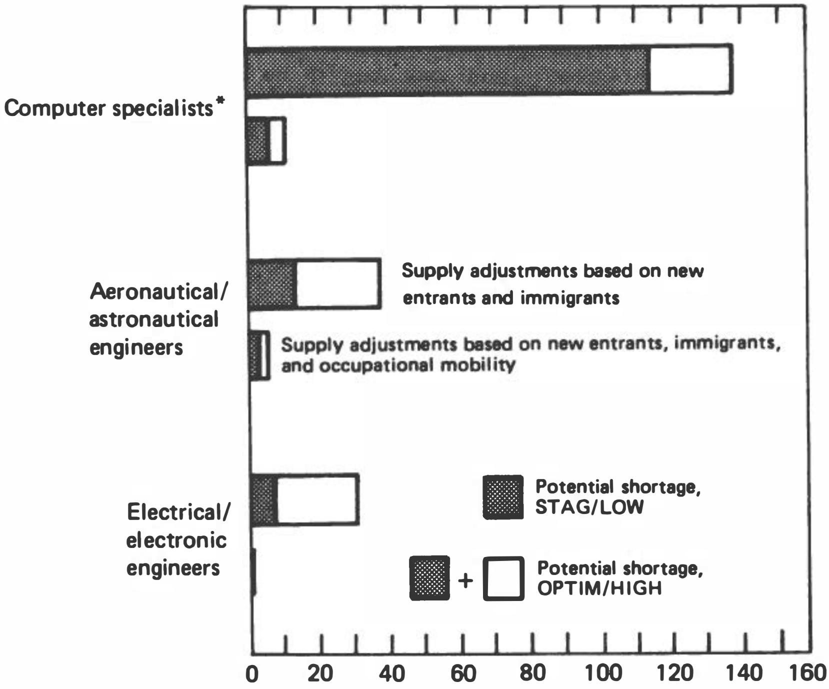
Aeronautical/astronautical engineering. Between 1982 and 1987, employment growth in this occupation is expected to out pace additions to supply from new entrants and immigrants, indicating potential labor shortages regardless of the levels of defense and nondefense demand being simulated. While available supply of personnel in this occupation appears 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 13,000-35,000 personnel (Table 4).

Employment in aeronautical/astronautical engineering is highly sensitive to cyclical swings in industrial performance. Subsequent to the running of our simulations, employment in aerospace industries declined significantly due to depressed demand for commercial aircraft. It currently appears that employment in these industries has stabilized, however, and may begin to grow in response to increased defense contracts, an improved commercial market, and sustained performance in missile and space industries. While a personnel shortage in this occupation may still develop by 1987, it appears unlikely at this time that it will be severe.

Occupational mobility within the experienced work force can alleviate potential personnel shortages when the supply of new labor-force entrants and immigrants is inadequate. If mobility is taken into account, projected shortages in these occupations decline dramatically (Figure 3).

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 2,000-4,500 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 (Figure 4).

The number of workers entering aeronautical/astronautical engineering from other occupations expands throughout the projection period to reach 11-15 percent of supply by 1987 (Figure 5). Inflows of experienced workers can be expected to come from both other engineering occupations and, to a lesser extent, from non-engineering occupations. In the case of the former, workers can be considered somewhat interchangeable because of common training in basic principles. Some of these personnel, however, will require extensive formal or on-the-job training that can result in substantial costs and/or production delays while still producing workers with insufficient work experience in the new field.



*Includes both computer systems and analysts and programmers.
NOTE: STAG/LOW indicates low-economic growth/low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth/high-defense expenditure scenario.

Figure 3. Potential engineering and computer speciality labor shortages (in thousands), 1987.

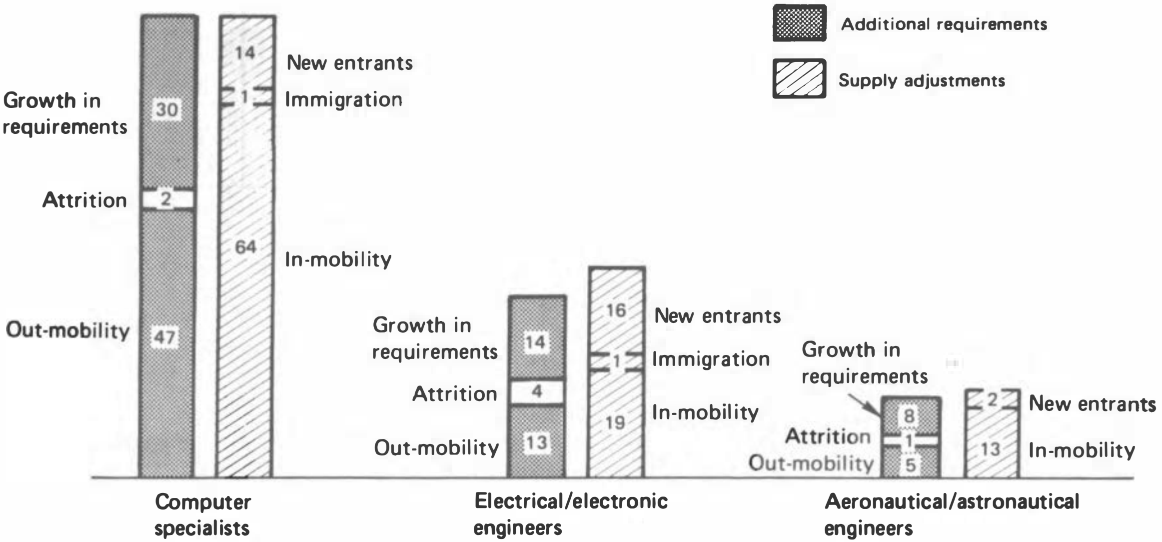


Figure 4. Labor-market adjustments to meet growth in requirements, 1987: High-economic growth/high-defense expenditure scenario (OPTIM/HIGH).

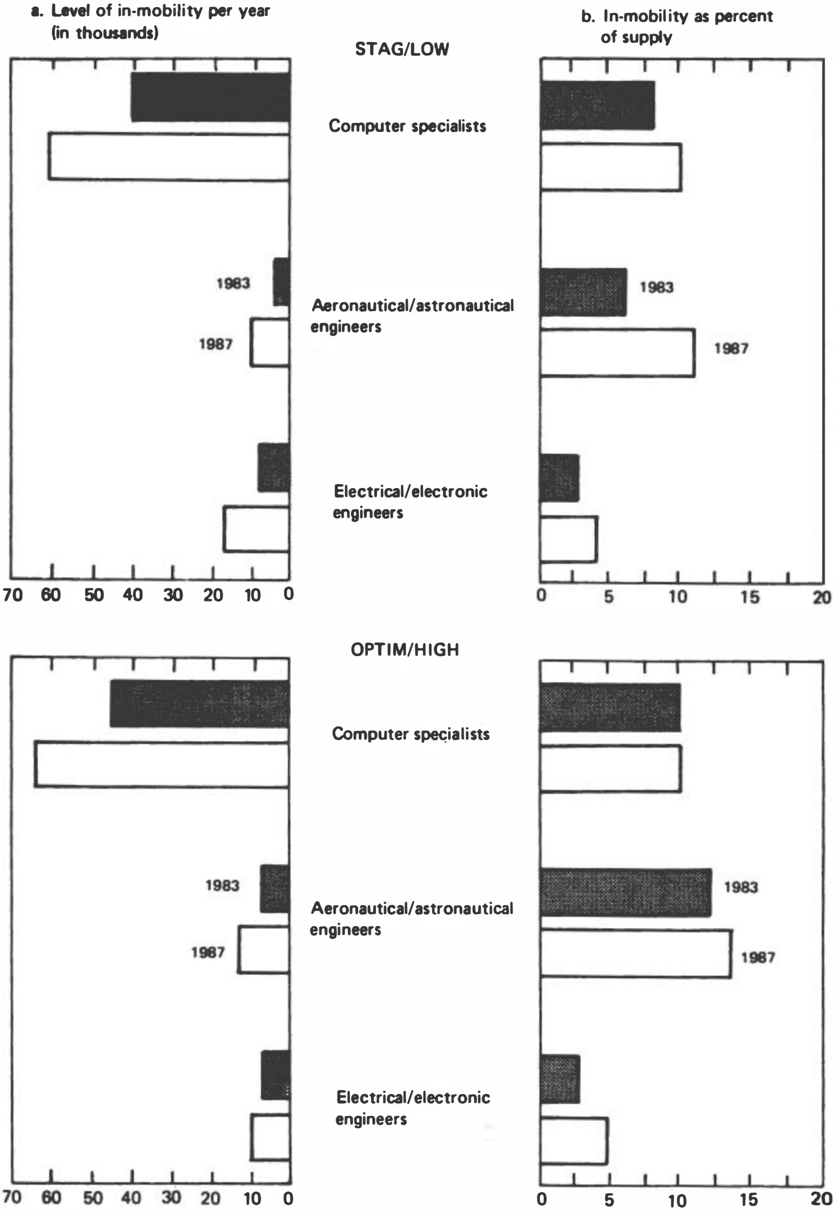


Figure 5. Dependence on in-mobility of experienced workers to reduce labor shortages.

During periods of extraordinarily high demand, experienced workers can also be drawn from non-engineering occupations including, for example, technologists and graduates from other disciplines. Such behavior was evidenced in the engineering market during the '50s and early '60s, when defense and space programs generated a rapid growth in demand for engineering skills. During this period, it was estimated that non-degreed personnel constituted as much as 25 percent of employed engineers.[9] Excessive reliance on such personnel also exacts costs and is an inadequate long-term solution to shortages of appropriately trained personnel.

Rapid employment growth in an occupation can also 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. Growth in the supply of new labor-force entrants can be achieved in either of two ways: students already in the pipeline can be encouraged to change majors, potentially straining the available academic capacity to produce such engineers; or as was evidenced in certain engineering occupations during the late '70s and early '80s, students could be enticed to forego advanced degrees so as to capitalize on available job opportunities. This latter behavior could reduce the future level of educational attainment among engineers. More importantly, however, it could also jeopardize the future supply of faculty needed by academia.[10]

Computer specialties. Data needed to model differences in the supply behavior of computer systems analysts and com-

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[9] 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).

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

puter programmers are not available; these two specialties are, therefore, combined for the analysis of labor-market balance. Growth in the supply of new labor-force entrants and immigrants in this combined occupation is projected to fall behind that of demand, 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 115,000-140,000 personnel.

Personnel shortages in this occupation can be alleviated only through large inflows of experienced personnel. Under the STAG/LOW and OPTIM/HIGH scenarios, computer specialty fields receive a dramatic infusion of workers from other occupations, reducing projected personnel shortages to within a range of 1.6-1.8 percent in 1987, roughly 9,000-11,000 workers. Labor market dynamics depicted by the supply model project 1987 increments to supply in the STAG/LOW scenario to include 59,000 experienced workers from other occupations 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.

The inflow from other activities plays an important role in computer specialty occupations 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 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 become increasingly more difficult to sustain. This will be especially true, over time, 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/electronics engineering. Employment of these engineers is expected to increase at an average annual rate ranging from 3.9 to 5.1 percent between 1982 and

1987. At low levels of defense spending, the labor market for electrical/electronic engineers is projected to be in balance even if supply adjustments are based solely on new labor-force entrants and immigrants. Under assumptions of high-defense expenditures, however, supply may be inadequate; 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, the high level of demand for these personnel induces a positive net inflow of workers. By 1987, labor-market balance is indicated across all scenarios, with the 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 experienced workers from other occupations, 15,700 new entrants, and 1,200 immigrants. While the rate of in-mobility required to alleviate potential personnel shortages is not as high as that required for aeronautical/astronautical engineers or computer specialists, it does increase over time, reaching almost 5 percent of requirements.

Conclusion

The relevant point to be made from this broad overview of labor-market conditions is that growth in demand is projected to create problems in relatively few occupations: computer specialties, which have had a relatively tight labor market over the past decade, as well as aeronautical/astronautical and electrical/electronics engineering, both of which are expected to be sensitive to the expenditure level and pattern of the defense buildup.

Despite the high levels of skill required in these fields, labor-market adjustments will occur even over a relatively short five-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 this work force. The larger the required adjustment, the more likely it would be that employers would be forced to hire individuals with inappropriate training and/or experience. This adjustment process is, itself, a manifestation of labor-market imbalances and can impose real costs not only in terms of employer-supplied training, but more importantly in terms of lower labor productivity (shortage indicators not manifested as unfilled job vacancies include the following: quality adjustments, salary escalation, rising nonwage benefits, retraining, increased overtime, and reduced/delayed production). Finally, the costs of current market adjustments can have an impact on future labor supply in these fields if the academic sector fails to retain necessary faculty or graduate students.

ENGINEERING MANPOWER AND EDUCATION: A PRECIS AND COMMENTARY

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Introduction

This paper summarizes the background, findings, analyses, and conclusions of an extended consideration of engineering personnel issues undertaken for and by the Business-Higher Education (B-HEF) in the early 1980s, culminating in a Forum report, Engineering Manpower and Education.[1] An understanding of the evolution of that study and of the Forum itself is important to the consideration of these views within the available spectrum of engineering personnel studies and projections. The author's views and interpretations of engineering manpower issues have been greatly influenced by the opportunity to work with the B-HEF in this study. Nevertheless, views and perspectives of this paper, particularly as they may depart from or go beyond the positions of the B-HEF Report, are the responsibility of the author.

The Business-Higher Education Forum was founded in 1978 as an affiliate of the American Council on Education. The intent, which has been fulfilled with noteworthy success, was to create a free-standing assemblage of leading corporate and academic chief executives that would come together on a regular basis to ventilate and act on the critical issues shared jointly by American business enterprises and higher educational institutions. The Forum seeks:

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[1] Engineering Manpower and Education--Foundation for Future Competitiveness, Business-Higher Education Forum, Washington, D.C., October 1982.

> . . . to identify, review, and act on selected issues and topics that relate to the current and future requirements of business and higher education;
> . . . to enhance public awareness of the concerns shared by business and academic leaders and to serve as a positive contributor in helping shape public policy thinking as it affects those concerns; and
> . . . to help guide the evolution of future relationships between corporate America and institutions of higher learning, while preserving their separate historical and traditional functions.[2]

The nexus of business and higher education encompasses many broad issues and policies: the vitality of American science and technology, economic development and renewal, international competition, and the concomitant shaping of the total social environment that enriches or limits the future growth of the people and organizations that make up this nation. All of these issues stand high on our national agenda. Early on, the members of the Forum recognized that the engineering manpower system, those many activities and forces that influence the immediate and longer-term market demand and supply for persons in engineering functions, was a critical, if seemingly uncontrolled, component of many of these central issues of public policy.

In early 1980 the Forum commissioned a preliminary study of engineering personnel issues. Those preliminary findings and recommendations were considered by the Forum members and by a Task Force comprising some Forum members augmented by a number of engineering deans and engineering managers from large, technically-based corporations. Development of commonly shared definitions, descriptions, and data within the widely differing perspectives on engineering personnel--both among the business representatives and among the academics--required time, patience, and multiple exchanges. The views and expectations did ultimately coalesce about several widely agreed-upon perceptions and, most important, upon a consideration of engineering personnel in terms of a transactional model. This model helped--or forced--the participants to recognize that both engineering employers and prospective engineering employees have available a true diversity of

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[2] *Op. cit.*, inside front cover.

choices and actions relating to engineering employment. Taken together with the recent state of the economy, these choices largely determine whether the immediate engineering manpower demand-supply relationship appears to be in balance or unbalanced by either unmet demand or excess supply.

The B-HEF study embodied--or more accurately, intersected--a phenomenon that has frequently been cited as an inherent characteristic of our engineering manpower system. B-HEF initiated this project in the winter of 1978-1979 with a sense of urgency motivated by industrial concerns that a shortage of personnel qualified to fulfill industry's identified needs would stand in the way of the capability of the nation's corporations to compete effectively in the then-perceived technological markets. By the time this study came to fruition in 1982, new engineering graduates, along with many engineers at later career junctions, were concerned that they could not find professionally challenging employment for their engineering skills and personal aspirations. This change gave pause regarding the essentially sanguine view that had emerged of the demand for new engineering graduates during the next decade. Further consideration of this immediate downturn in the demand for engineers--in terms of the overall economic conditions, the available current employment data and anecdotal information, a transactional approach to manpower issues analysis, and reconsideration of the facile claim, too-often repeated and too-quickly accepted, that the supply and demand for engineers are inherently "cyclical"--did not counter the essential conclusion of this B-HEF study that, barring a continuing major recession and allowing for some inevitable geographically-, chronologically-, or industry-specific negative impacts, the overall integrated demand for engineers would remain adequate and in most conditions strong.

The B-HEF Engineering Manpower Study

This study was designed to take advantage, to the greatest possible extent, of available data and the knowledge, insights, and impressions of the experienced personnel who were concerned with engineering personnel issues in the four principal agencies involved in ongoing data collection, analyses, and projections: (1) Engineering Manpower Commission (EMC) of the American Association of Engineering Societies (AAES), (2) the Bureau of Labor Statistics (BLS) of the Department of Labor, (3) the Scientific and Technical Personnel Studies Section (STPSS) of the National Science Foundation, and (4) the National Center for Education Statistics (NCES) of the Department of Education. All of the individuals contacted were helpful beyond any normal requirements or expectations, and the specific contributions of many individuals are cited in the notes of the Forum report. What was most important was the opportunity to discuss and speculate about why certain trends were observed, why some data were not available and hence are approximated or neglected, why the data were aggregated or disaggregated in a particular form or component, and how these elements might interact in the actual marketplace choices of employment. An early realization was that many data that have been or are reported for engineers, engineering employers, engineering position, etc., stray far from the common Stein-like expectation that an engineer is an engineer is an engineer.

A definitional question of who (or what) is an engineer is present, if not manifest, in every consideration of engineering personnel data: an individual who has graduated from a recognized engineering program? an individual who self-identifies as an engineer? an individual with functional responsibilities that an employer or the public identifies as engineering? all, some, or none of the above? In recent years, engineering demand and employment data appear to be converging on an engineering population identified by any two out of three qualifications: self-perception (self-identification), employer-defined functional responsibilities, and education. This still leaves considerable uncertainty. An "engineering" position (demand) may subsequently be filled by an individual who will not qualify as an engineer under this 2-out-of-3 criterion. An engineering graduate may choose to self-identify as an engineer even when employed in a patently non-engineering function.

There is a second problem associated with this definitional looseness. Once individuals or positions are identified as part of the engineering personnel pool, or employment demand, the very real differences that exist among the qualifications of divers individuals or among the functional requirements of divers positions are lost, or at least neglected. In fact, engineers and employers both recognize a significant hierarchy of desirability and benefits in considering alternative possible matches of an individual and a position.

This hierarchical character of these choices is easily perceived when the usual supply and demand figures for engineering personnel are broken down to identify the numbers of specific transactions expected on the supply side or on the demand side of the total engineering employment pool. With few exceptions, employers do not gain the same resources and benefits (and certainly not in the same time frame) by hiring an available baccalaureate graduate in technology or physics to provide functional output formally provided by a B.S. graduate in an appropriate engineering discipline.

An open system model of the engineering (and pseudo-engineering) shown in Figure 1[3] provides the background for further consideration of the engineering employment projections developed by BLS and the other agencies cited earlier. This figure, reproduced from the B-HEF report, reflects the then-available data and preliminary BLS projections. The numbers will change as more recent data and projections are substituted, but the important insights and implications of these considerations will not be substantially altered.

Several clarifications are needed. This analysis focuses on the comprehensive industry, government, and private-practice employment of engineers. It is predominantly concerned, therefore, with B.S. and M.S. engineers and does not represent the special problems associated with the supply of, and demand for, Ph.D. engineers. Academic employment is not included, although these data may be available in more recent BLS projections. This analysis of personnel transactions also neglects the effect of B.S. graduates who defer or interrupt employment to return to full-time graduate study and subsequently reenter the employment market as M.S. graduates. The data for these transactions were insufficient to do anything other than to assume that they just about balance. Similarly, the analysis in Figure 1 neglects the small numbers of B.S. or M.S. graduates who enter into full-time doctoral programs. New B.S. engineering graduates continue to be the dominant component in supply.

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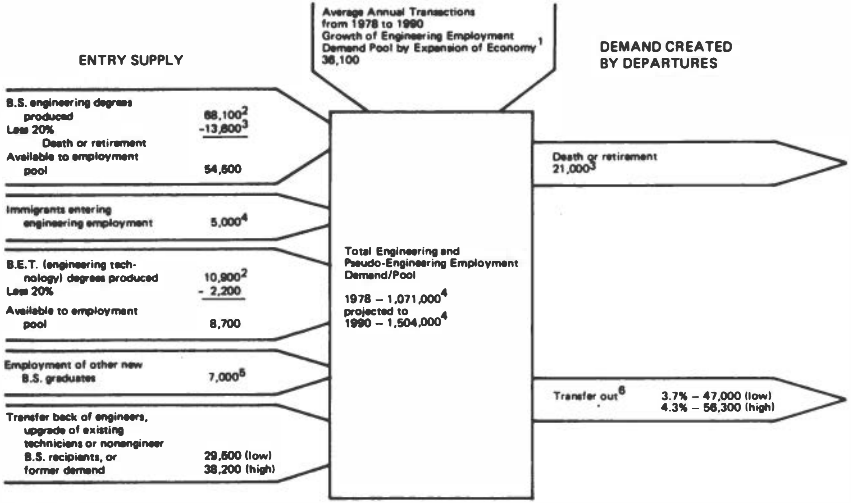
[3] This graphical presentation of these data follows the approach taken by Dr. Robert Stambaugh in a discussion of an early draft of the B-HEF report.



[1] M. L. Carey (Bureau of Labor Statistics), "Occupational Employment Growth Through 1990," Monthly Labor Review, August 1981. These data from "low" growth projection.

[2] Averages determined from values of Table 18 in National Center for Education Statistics, Projections of Education Statistics to 1988-89 (Washington: GPO, April 1980); and 1990 values from NCES Bulletin 81-406, February 13, 1981.

[3] Occupational Projections and Training Data, 1980 Edition, Bureau of Labor Statistics, U.S. Department of Labor Bulletin 2052, September 1980. The 20% figure is probably conservative in light of the increasing enrollments of nonpermanent foreign nationals in engineering programs.

[4] BLS estimate. This estimate is consistent with W. P. Upthegrove's impression that about one-half of foreign nationals who take B.S. or M.S. degrees in U.S. engineering colleges eventually stay in the United States.

[5] Unpublished data compiled in 1978-79 by Daniel E. Hecker, Bureau of Labor Statistics.

[6] Survey of engineering employment 1974-1976 suggested an average transfer-out of 3.7%. More recent surveys have indicated an even higher rate (unpublished Bureau of Labor Statistics data from Daniel E. Hecker).

Figure 1. Projected engineering manpower transactions, 1978-1990.

Demand

This presentation emphasizes three major components in demand:

(1) The increase in the employment pool created by projected expansion of the economy treated as a linear increase over the 12-year period of these projections,
(2) The demand created by expected death and retirements, and
(3) The demand created by "transfer-out" of engineering-qualified personnel from engineering functional positions. These transfers were identified in the returns of a BLS survey of engineering employment from 1974 through 1976. At that time, the survey data suggested that transfer-out transactions affected roughly 3.7 percent of the employed engineers in any one year, an average annual loss of 47,000 engineering employees. Subsequent BLS surveys suggested that the engineer transfer-out rate might be a large as 4.3 percent. These surveys have also begun to track transfer-back transactions. This phenomenon is substantial but less than the transfer-out rate. More recent data and the introduction of results from use of both the most recent projection model and transfer-out rates generate a substantial average demand annually for engineering positions through 1990.

Many members of B-HEF express views that this economic-model-driven projection of demand was probably low because it is difficult to pick up all of the forces that are added to the demand for engineering employment--including the continuing development and rearmament of the U.S. defense establishment, extending over many years; the continuing need for more effective use of limited energy and material resources; the expanding direct-service roles of engineering consultants in both traditional and new fields; the continuing expansion of technologically based governmental programs and activities; the increasing penetration of new technology (microprocessors and other integrated circuit capabilities, new materials, etc.) into all industrial and service activities; and a concomitant yet broader advance in the rigor and level of most engineering functions. What is both persuasive and reassuring about the demand generated by these trends is the diversity and breath. It is not, as some earlier engineering patterns were, a single-dimension demand dependent on one consumer and one objective.

On the other hand, the overall demand will (as has been manifest in 1982 and 1983) still be subject to short-term fluctuations and to major long-term economic shifts. The issues of manpower planning and resource allocation, particularly insofar as the allocation of educational resources is concerned, cannot be done in isolation. That is, the vagaries of engineering demand should be examined in the context of total human resource demand-supply consideration. The lessened demand that engineers are experiencing today is still substantially higher than the demand for other comparable professional baccalaureate graduates, and future engineering demand will rise with, or even lead, a renewal of our overall economy.

Supply

The supply components offer employees a set of choices that are both strongly hierarchical and also very flexible. The largest and most important single component is the input of new B.S. graduate engineers. These degree projections were reduced by 20 percent; currently only 80 percent of the engineering B.S. graduates actually enter U.S. engineering employment.

The projections of new B.S. engineer entrants were lower than the earlier projections. Moreover, the actual number of degrees granted for the first three years of these revised projections (1978-1979, 1979-1980, and 1980-1981) had consistently lagged the projected levels by 8-9 percent.

The estimated level of immigrant engineers is based on historical data. Recent growth in the enrollments of foreign students in U.S. undergraduate programs suggests that this number could increase if the U.S. Immigration and Naturalization Service again recognizes engineering as a critical profession. On the other hand, this component of the supply is seriously threatened by many of the immigration bills proposed in the past 18 months.

The estimate of Bachelor of Engineering Technology (B.E.T.) graduates available for hiring in pseudoengineering roles is based on projections that, like those for B.S. engineering degrees, exceeded the actual number awarded in 1978-1981. The limited information on B.E.T. employment suggests that the percentage of B.E.T. graduates not entering the engineering employment market will be comparable to that for B.S. engineering graduates.

Employment of new B.S. recipients from the other physical sciences and mathematics may expand beyond these estimates, but no great surplus is obvious in these fields. Moreover, many mathematics and physics graduates will undoubtedly be recruited to help fill demands in computer science. A significant number of engineering graduates may also find the opportunities in computer science attractive and thus further reduce the supply of new engineering employees.

Insufficient data are available currently to project accurately the potential contributions of back-transfer and upgrades. Such transactions, however, are unlikely to reach the levels needed to meet all projected demands.

Supply-Demand Balance

The existing engineering manpower system, as described in Figure 1, has a great deal of built-in elasticity. As a consequence, and barring an extended major recession, the engineering employment market will also always generate adequate, and in most cases abundant, employment opportunities for new B.S. engineering graduates. The system also provides industry with a hierarchy of options for meeting, with varying levels of satisfaction, their demand for technical personnel when it exceeds--and it usually does--the supply of B.S. engineering graduates. However, when any industry is forced to employ too large a proportion of less-than-fully-qualified persons in areas of nominal engineering responsibility, its technological and economic competitiveness is inevitably diminished.

Thus, Figure 1 suggests serious concerns about the supply of B.S. engineering personnel available over the remainder of the decade. If the out-transfer rate approaches 5-6 percent as some earlier trends suggest and if a transfer-back to technical functions does not grow even more rapidly, there will almost certainly be a substantial imbalance between supply and demand.

The obvious ways to reduce this imbalance appear to be either to increase the number of B.S. graduates produced by our engineering colleges or to let an increasing number of the engineering positions be filled with marginally qualified persons with the risks noted above.

The prospect of trying to increase the numbers of new

B.S. engineering graduates beyond those currently projected is equally questionable. No proven model is available to guide a commitment to increase the output of engineering programs. In general, engineering enrollments increase when there is a reasonable or strong employment demand <u>and</u> a general social acceptance or support for the tasks and contributions of engineering. How that conjunction might be promoted as a development strategy is not clear. Second, the present high student-faculty ratio, the shortage of new faculty members, and the limited instructional facilities make it impossible to maintain quality <u>and</u> increase enrollments. Indeed there is strong, but still incomplete, evidence that the reduced employment demand of the past two years has already reduced the number of students seeking entry to engineering programs.

Closing

This precis has focused on those parts of the Forum report concerned with supply and demand issues of engineering employment at the M.S. and predominantly B.S. levels. The Forum report addresses a range of associated topics and interested participants are encouraged to peruse the entire report.

The B-HEF study concluded that ". . . barring an extended major recession, the engineering employment market will almost always generate adequate, and in most cases abundant, employment opportunities for new B.S. engineering graduates." The experience of the past two years has certainly emphasized just how uncertain and non-quantitative the adjectives "extended major" are. Notwithstanding that reservation, the basic inference drawn from this reexamination is that the engineering manpower system will provide diverse, challenging, and in most cases, extensive opportunities for the foreseeable supply of new B.S. engineering graduates to enter their chosen profession.

SUMMARY OF DISCUSSION

Following Pat Hill HUBBARD's description of the AEA study, Richard ANDERSON inquired about the difference between the projections resulting from the 1981 survey and the actual growth figures in 1983. He pointed out that while the overall over-projection was 5 percent, the growth that was projected was probably 50 percent off; only half of the growth projected actually occurred. An effective method for determining shortage is to watch for increases in price, but Anderson observed that the salaries for new engineering graduates have not shown marked increases. This leads one to believe that the demand for electrical engineers has not exceeded the supply. Accordingly, ANDERSON was troubled by the AEA's projected growth in demand of 10 percent when growth rates in the past have been closer to 5 percent.

HUBBARD replied that many factors can influence growth rates for engineering employment. It is very difficult this near to the recession to determine why the electronics industry did not fill the projected positions--whether defense contracts were not obtained, whether companies were unable to secure capital to expand, etc. However, AEA data show that salaries for new electrical and computer engineers have not been constant; there has been a healthy growth rate. For experienced engineers, HUBBARD agreed that salaries have not risen at an adequate rate.

While Paul DOIGAN concurred that there is a need for electrical and computer engineers, he did question the magnitude of the shortage projected by AEA. The first problem is the fact that a number of the firms surveyed may be bidding on the same contracts, particularly in defense areas. The magnitude of the openings that disappear when those contracts are awarded is unclear. Second is the survival rate of electronics companies, which we understand to be two of five for Silicon Valley firms. Again, might a substantial factor in these projections be wishful thinking on the part of these companies? Many of these firms may be taken over by a larger company. In the recent oil industry mergers, for example, the rate of exploration for new oil sources and, in turn, the numbers of new openings for geologists are likely to decrease.

HUBBARD noted that many factors are not taken into account by the AEA projections, including the movement of engineers into management and the demand for computer engineers by other industries. The survey was never intended to provide that level of precision. As far as the survival rate of electronics industry companies, AEA membership data show a steady growth rate in all size categories--including start-ups--during the last seven years. We see a continued, healthy new-company addition.

Robert WEATHERALL noted the methodological problem in asking competing companies about their plans and projections. Some are likely to lose as much market share as others will gain. One should rather ask the companies for projections of product lines, obtaining the collective wisdom of the industry on growth in product lines, and then translate this growth into the number of professionals needed to support these products.

HUBBARD agreed that this approach would provide more reliable projections. However, when AEA attempted a product-line survey, we found that companies would not participate. Many firms had all of the 26 product lines identified by AEA but did not have the capability of making business plans on a product-by-product basis. We have found it to be simply a monumental effort to obtain even the basic information we now receive from the companies.

Discussion of Ronald KUTSCHER's presentation of the Bureau of Labor Statistics' supply/demand model began with a question from Herbert RABIN concerning the accuracy of BLS projections over time.

KUTSCHER replied that the BLS regularly evaluates their projections and has done so for those published in 1970, 1975, and 1980. While the average error rate for occupations is roughly 12 to 14 percent over a 5- to 10-year period, there is considerable variation within occupations. Consequently, for some occupations BLS projections can be almost exactly correct, and for others the projections can be off by a substantial margin. For engineers, BLS over-projected the growth by about 1 percent per year over the 1960-1975 period. The 1970-1980 projections were very close to the actual growth in engineers, but again this accuracy varied among individual engineering fields.

Fred LANDIS asked for clarification on Kutscher's statement that 80 percent of engineering graduates enter the profession. Does that figure exclude those going on to graduate study in engineering? KUTSCHER replied that the 80 percent figure includes all those entering engineering-oriented occupations. The 20 percent represents individuals going on to work in fields unrelated to engineering.

Daniel DRUCKER noted that the BLS projects that if past trends continue, then the quantity of supply of engineers should be in balance with the demand. Is any thought given to the quality of engineers, and how following the pattern of the past may effect our world competitiveness?

KUTSCHER replied that BLS did not have any way of answering the question of whether the past levels of engineering expertise are good enough for the future. The labor-market situation that BLS sees is not a radical change from the past. In fact, if BLS projections of demand are a bit high and supply a bit low, then over the near-term, condi- tions may improve somewhat.

Charles FALK continued the discussion of the quality issue by asking to what extent one should define shortage as the discrepancy between demand and the number of new degree-holders entering the market. Responses to a 1983 NSF survey of 350 large technology-oriented companies showed that less than 10 percent reported shortages of electrical engineers, down from 60 percent in 1981. Given the BLS assumption that 50 percent of these new entrants are not engineering degree-holders, do such results indicate that employers are satisfied with the state of the labor market? Is this apparently low shortage level satisfactory from a quality point of view?

HUBBARD replied that the larger companies, which formed the group that NSF surveyed, seem to have more success in attracting engineers by offering highly competitive salary and compensation packages than do the smaller, more dynamic companies. Moreover, HUBBARD maintained that employers would not be satisfied with 50 percent of their new hires coming from what they would perceive as less-qualified individuals: our ability to maintain world competitiveness is very important in specialty areas. As the computer field becomes increasingly complex, a physicist simply cannot be rapidly translated into a computer engineer, and this has a negative impact on productivity.

KUTSCHER pointed out the broad public-policy question involved here: because no one can predict with certainty the categories of skills needed ten years in the future, what is the implication of employers not willing to hire someone from another field? If an individual makes the wrong guess, for example to go into physics when we need electrical engineers, should this person be delegated to the "scrap heap" at a relatively early age? It is probably true that using those individuals may be less efficient than hiring all new graduates, but we should be concerned with what happens to those who may have chosen the wrong degree field and find themselves, at age 35 or 45, in a field where there is no demand.

Charlotte **KUH** spoke to the issue of future needs for computer specialists as described in Jean Vanski's paper. **KUH** noted that over the next 10 years, shortages of computer specialists are likely to disappear because computers will be doing what programmers are now doing. In fact, today many jobs that programmers used to do are simply wired into machines. This substitution of capital for labor with computer-assisted design and engineering results in a permanent decrease in the demand for programmers.

HUBBARD replied that although that is partially true, many computer specialty areas are going to remain fairly static, and the in-mobility from other areas will be increasingly a non-solution. Retraining people with no computer education for computer occupations is not going to be advisable in the future because the specialties are going to be increasingly exact. We are going to need higher-qualified computer people, and that will restrict in-mobility.

Alan **FECHTER** reiterated **KUH**'s point by stating that in addition to the possible adjustments mentioned in Vanski's paper that would equilibrate the labor market, this capital-labor substitution could become a significant factor in the future.

COMMENTARY BY DISCUSSANTS

A REVIEW OF FOUR STUDIES

W. Lee Hansen
University of Wisconsin-Madison

The four papers prepared for this symposium attempt to answer the question posed in its title: "Is There a Shortage?" The assignment to comment on these papers is formidable for several reasons. First, differing views among knowledgeable experts about what constitutes a shortage make it difficult to know what benchmarks to employ in evaluating the evidence presented in the papers.[1] Second, the papers include findings from several other studies that when combined with the oral presentations here today diffuse my sense about what information is most pertinent for these comments.[2] Third, differences in the time reference periods for the projections--with one focusing on the short-run, another on the long-run, and the other two on the in-between--mean that the results are not directly comparable. Finally, the authors of the papers are all reticent about offering a precise answer to the question, recognizing as they do, the problems that arise because of the nature of

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[1] National Science Board, Scientific and Technical Manpower Projections: Report of the Ad Hoc Committee on Manpower, Washington, D.C., October 1974, and Scientific and Technical Manpower Projections: Proceedings of the Seminar, Washington, D.C., October 1974.

[2] Reference is made in the ACE report to several other studies. The same is true of the NSF report. In addition, several other NSF surveys have attempted to ascertain labor-market conditions for science and engineering graduates: Science Resources Studies Highlights, NSF 82-310 (June 9, 1982), NSF 82-330 (November 22, 1982), and NSF 84-303 (January 1984).

the data and methodologies and because of the varying interpretations that can be attached to their results.

Rather than concentrating on arriving at a judgment about whether the papers demonstrate clear evidence of a current or prospective shortage of engineers, I propose to examine each paper and try to indicate what it can and cannot tell us. My hope is to help us learn more about how to assess the state of the labor market for engineers, emphasizing what must be done to improve our knowledge so that, say, five or ten years hence, we will be better equipped to answer the question that brings us together.

American Electronics Association (AEA)

Three questions guide my discussion of this report. What can we learn from this quite different report that we cannot learn from the other reports? What else could we learn from a more complete analysis of the survey data underlying this report? And how might the results of this report be used to evaluate the presence of a shortage? In answering these questions, I find it necessary to draw not only on the 1983 report but also on a similar AEA report published earlier.[3]

Before proceeding, it must be said that the AEA is to be commended for attempting its survey. The results help throw light on the evolution of the rapidly expanding electronics industry. The early release of the reports provides a wide range of benchmark data, projections of employment demand, and an array of answers to related questions that help put the projections into perspective. The information in the AEA report differs fundamentally from that employed in the other three studies by reflecting the informed judgments of people in the industry rather than the explicit assumptions that necessarily underlie the usual projection models.

Technical Issues

The results from the 1981 and 1982 surveys would have been more useful had it been possible to weight the data

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[3] American Electronics Association, Technical Employment Projections, 1981-1985 (Palo Alto, CA: 1981).

for differences in the characteristics of those firms that did and did not respond. Given that the response rates were below 50 percent and lower in 1983 than in 1981 (38 versus 48 percent), we are not in a good position to interpret the 1983 results or compare the 1981 and 1983 results. Several bits of evidence lead to this conclusion. First, the distribution of firms by size differed considerably, with 36 percent of the responding firms having more than 200 employees in 1981 as compared to 47 percent in 1983. Second, even though the response rate fell, the number of responses jumped by more than 20 percent (from 671 to 815), implying that the industry grew rapidly (which it no doubt did), membership in the AEA expanded dramatically (that also appears to be the case), or some combination of the two. This evidence indicates quite clearly the need to weight the data, not only so that comparisons can be made over the two years but also to give the industry a better sense of the labor market for technical personnel.

Whether the required employment weights can be obtained for non-responding firms to yield total industry employment is a question I cannot answer. In view of the growth of the industry and the absence of other benchmark data, the difficulties of obtaining the information needed are formidable. It seems clear, however, that the AEA should do what it can to develop a weighting scheme for future as well as past reports, both to alleviate concerns of readers about the nonrepresentativeness of the responding firms and to enhance the usefulness of the published data.

Matched Firm Comparisons

The fact that this is a survey of member firms from an association means that substantial numbers of respondents answered both the 1981 and 1983 surveys. This should make it possible to analyze the responses of those firms for both years. Such an analysis could yield valuable information on the stability of the projected employment levels. The resulting comparisons would necessarily exclude employment by new firms (also by new members of the AEA) as well as by older firms that ceased operations; that is inevitable but in no way denies the usefulness of matched firm comparisons. Similarly, because some firms responding to the 1983 survey could not provide projections over the full five-year period, it would be informative to show projected employment for those firms that did provide annual projections over the entire period. It would be even better if the information for this subset of firms could be weighted to show projected employment totals.

Fuller Exploitation of the Data

In future surveys I urge fuller exploitation and analysis of the survey data. The information is rich in analytical possibilities, but as so often occurs, the pressure to produce a report quickly and lack of analytical expertise lead to a woeful underutilization of the available information. What might be done? It would be useful to know how projections differ depending on the position the respondent holds in the organization. Given that such information was obtained, it would be possible to compare the projections put forward by planners, chief executive officers, and others. How different are their projections? Are the differences associated with the person or the approach they use? What leads to different assessments of the labor market? In addition, the influence of economic conditions could be understood more fully by examining how differing perceptions of the state of the economy influence the level of projections. Finally, adaptations and adjustments to labor-market conditions could be explored by comparing how the projections vary, depending on perceptions of supply-demand relationships, perceived causes of labor market problems, possible accommodations to shortfalls of personnel, and recruitment methods.

A continuing difficulty with employer-generated projections is the myopic view they so often reflect, i.e., their own immediate view of the market without respect to the behavior of competitors or the larger economic situation. Given the volatility of the economy and especially of the most rapidly growing sectors, systematic over- and underprojections of demand for personnel are likely to occur over any extended period of time.

Accuracy of Projections

The usefulness of projections depends ultimately on the accuracy of the information they provide. How one assesses the accuracy of projections is difficult to know because the very publication of projections is likely to alter the behavior of responding (as well as nonresponding) firms, of individuals employed in these firms and closely related firms, and of people preparing to enter the industry. Nonetheless, one simple test is to compare the actual and projected employment totals as the 1983 report does for the projections coming out of its 1981 report. To the extent that markets respond to projections that might imply shortages or surpluses, projections cannot by their very nature earn high marks for accuracy.[4] Putting these issues aside, I argue that the published conclusions about the accuracy of the projections are misleading.

The report indicates that while it is premature to make judgments about the accuracy of the industry projections, the projection made in December 1980 of total jobs for 1982 shows a remarkable congruence with actual employment at the end of 1982. This conclusion is reached by extrapolating the survey results to industry totals by applying some crude employment weights (this is the only instance in which any weighting is done) to projected 1982 employment and actual 1982 employment. The report concludes that 1982 employment exceeded that projected for 1982 by 4.8 percent. It goes on to note that the accuracy of the projections for particular categories of technical personnel was less good, as might be expected for subgroups of some larger total.

To set the stage for this discussion, the dating of the projections must be understood. As indicated by the column headings in Table 1, the 1983 report offers projections of new employment for December 1983 (also for December 1984, December 1985, and December 1987 but not shown in the table), with December 1982 employment as a base. The 1981 report is less clear but projects new employment for what appears to be December 1981 and December 1983, with December 1980 employment as a base. This discussion will concentrate on total employment of technical personnel, presented in the top part of Table 1; additional information is available and shown for the two major categories of technical personnel, namely, professionals and paraprofessionals.

It should be readily apparent that no direct comparisons can be made so far between actual and projected em-

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[4] W. Lee Hansen, "Labor Force and Occupational Projections" in Gerald Somers (ed.), Proceedings of the Eighteenth Annual Meeting, 1965, Industrial Relations Research Associations, Madison, Wisconsin, 1966.

TABLE 1. Actual Employment, Projected New Employment and Projected Gross Employment, for Technical Personnel, Technical Professionals, and Technical Paraprofessionals, 1980-1983, based on American Electronics Association Surveys

	Employment Levels (in thousands)*			
Type of Employment and Source of Data	Actual Levels Dec. 1980	Projected Increase to Dec. 1981**	Actual Levels Dec. 1982	Projected Increase Dec. 1983**
Total Technical				
1981 Report	289	+63 (352)		+101 (453)
1983 Report			371	+43 (414)
Professionals				
1981 Report	146	+30 (176)		+44 (210)
1983 Report			167	+23 (190)
Paraprofessionals				
1981 Report	143	+33 (176)		+57 (233)
1983 Report			203	+20 (224)

*Totals do not always add because of rounding.
**Figures in parentheses reflect "gross employment" levels and are the sum of actual employment levels and subsequent projected increases in new employment.

SOURCES: American Electronics Association, Technical Employment Projections, 1981-1983-1985, Palo Alto, California, 1981, pp. 24-25; American Electronics Association, Technical Employment Projections, 1983-1987, Palo Alto, California, 1983, p. 24.

ployment, since there are no projections for December 1982. What the AEA report apparently did was to compare the 1981 report's projected employment for either December 1983 or some interpolated figure for December 1982 with the 1983 reports actual employment for December 1982. Unfortunately, the origin of the 1982 figure for projected employment for the 1981 report is not identified. If the comparison is for December 1983 projected employment and December 1982 actual employment, this is clearly an invalid comparison. But even if the comparison is with an interpolated figure for December 1982,[5] one cannot simply add the number of projected new jobs to December 1980 employment to obtain December 1982 projected employment. This is because actual December 1982 employment is the sum of December 1980 employment and new employment to December 1982, minus the number of retirements, deaths, terminations, and moves to other jobs. New employment is defined explicitly to exclude all forms of attrition. So without additional information on attrition, the 1983 report's implied employment total for December 1982 is misleading unless we describe it as a gross employment total. But then it is not comparable with actual employment in December 1982.

Comparing Levels and Changes

The comparison used by the AEA centers on employment levels, noting that its projected employment fell short of actual employment by 4.4 percent. Aside from the difficulties mentioned above, the measured accuracy of projections should depend on what is being projected. Suppose we want to compare the projections of new employment for 1983 made in the 1981 and 1983 reports. Suppose also that we take the 1983 report's projection as a benchmark against which to compare the 1981 report's projection. The 1981 report projects 164,000 new jobs by December 1982 which, when added to the December 1980 total of 288,000, yields a gross employment total of 453,000; this contrasts to a gross employment total of 414,000 for December 1983 from the 1983 report, obtained

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[5] If the plan was to interpolate for December 1982 based on December 1981 and 1983 projections, then the resulting base figure for the AEA's calculation should be 401,000 rather than 389,000.

by adding the December 1982 employment base and new jobs to December 1983. Since 453,000 exceeds 414,000 by 39,000, this means that the 1981 report's projection overstated the 1983 report's projection by 39,000--which, when divided by 414,000, yields an error of +9 percent.[6] (This percentage figure differs from the 4.4 percent figure mentioned earlier, in part because different dates are used but also because these figures are not weighted.) This accuracy rate might by some standard be viewed as reasonably good.

And yet the AEA questionnaires asked for projections not of levels but rather of increases in new employment from the base period. This means we must compare changes rather than levels. How accurate were the projected changes? From the 1981 report we observe that employment, starting from a December 1980 base of 289,000, was expected to be augmented by 164,000 new jobs by December 1983. Meanwhile, from the 1983 report we see that projected gross employment for December 1983--414,000--represented an increase of 125,000 jobs over the December 1980 base. Thus, to determine the accuracy of the projections, we must divide the change of 164,000 by 125,000 --which indicates that the projected addition from December 1980 was about 30 percent greater than that seen as of December 1982. A 30 percent error for changes is considerably less impressive than the 9 percent figure calculated for levels.

Might one have done about as well by simply extrapolating past growth patterns? Who knows? Such extrapolations would be useful in giving readers additional information, thereby allowing them to compare the employer-generated and simple-trend projections. Making such trend projections is not a straight-forward task, however, because one must choose the method of extrapolation--straight-line, exponential, quadratic, or whatever; each produces quite different results.

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[6] This illustrative comparison is flawed because actual December 1982 employment is a net figure, with new additives since December 1980 being partially offset by attrition over that period. If gross employment in December 1982 could be ascertained, it would be greater than 371,000; and this difference would have to be added to the projected gross employment figure of 414,000 in December 1983.

Is There a Shortage?

The report, while not explicit about whether there is a shortage of all engineers, provides some evidence of shortages for particular types of engineers. The difficulty with its conclusion is that it provided no criteria in the questionnaire to guide respondents in deciding whether they faced or were likely to face shortages. The projections of demand or of new jobs tell us nothing about possible shortages; for this we need additional information on supply. Nonetheless, a third of the respondents expressed the belief that a general shortage existed for electronics-electrical and computer software engineers. Another quarter thought some shortages existed but were confined to particular specialty areas. Still another quarter indicated that while shortages did not currently exist, they would develop as the economy returned to its 1980 level of economic activity. The remaining fifth thought there was no shortage.

How do we interpret these data, assuming that respondents answered consistently? Just over half of all respondents thought that a general or particular shortage existed at the time of the survey. Do the views of this group reflect the true state of the labor market? Or is the fact that well over 40 percent of the respondents thought that no shortage currently existed sufficient to dismiss the claims of shortages? How do we factor in the observations of another fifth of the respondents that shortages would exist if the economy returned to its 1980 level? As of February 1984, it had not. Thus, I suppose we could conclude that because the vote was about evenly split as of late 1982 and because conditions had not changed enough by early 1984 to alter that split, the evidence is mixed.

Summary

My remarks, while they may seem critical, are meant to be constructive. Surveys of employers, unlike the approaches of the other papers, obtain information on current and prospective labor-market conditions as seen by the people who are closest to the market. Moreover, the information obtained is far richer than that utilized in the more sophisticated projection models. But the raw data by themselves can answer only a limited set of questions. To squeeze more out of the data requires analyses that probe the data to establish quantitative and qualitative relationships that can help illuminate the dynamics of labor markets. So, I urge the AEA not only to continue its surveys but also to sharpen the analysis so that we can learn more about one of the most important and fastest growing sectors of the American labor force.

American Council on Education (ACE)

The American Council on Education report provides a good description and summary of other studies; it integrates the results of other studies into a useful schematic for assessing labor-market balance, and it offers recommendations for action. The focus of its recommendations is on assuring the availability of a key component of the engineering education infrastructure--namely, college and university engineering faculty members. The report calls for, among other things, improved faculty compensation and more fellowships to attract American undergraduates into postgraduate scientific and engineering programs.

The schematic encompasses the ACE's projection of engineers, which is really an amalgam of results from other studies, and highlights the relationships between stocks and flows. What it does not do is indicate the nature of the behavioral assumptions that produce these various flows. Nor is a close link established between the assessment of the market for engineers and the recommendations that deal with the academic market for engineering faculty members. But we cannot be too critical because the purpose of the report is not to devise a new approach to projections but rather to mobilize the higher education and business communities to take action on the growing imbalance between the academic and nonacademic labor markets for Ph.D.-trained engineers.

The report might have done a useful service by calling for more explicit attention to understanding how the labor market operates for Ph.D.-trained engineers. Such a model might go something like this. It would begin by attempting to understand the determinants of the flows of high school seniors into engineering programs, their choice upon graduation to enter the work force as compared to beginning graduate study leading to a Ph.D., and if the latter, their decision to persist to complete the Ph.D. degree. Then they face the choice of seeking academic employment as against nonacademic employment; to the extent they choose the former, we must then follow their choice to continue in the academic sector in the face of attractive outside job offers. Modeling this labor market would be an interesting and challenging task, and the results would very likely provide a strong rationale for the recommendations noted above and perhaps other recommendations as well.

In recent years various attempts have been made to model labor markets for people with advanced training where the long training pipeline precludes rapid adjustments to changing demand conditions. Applications have been made to the labor market for such groups as college faculty members,[7] Ph.D. economists,[8] and mathematicians.[9] With such models it should be possible to estimate the size of salary adjustments needed to prevent, if not reduce, the outflow of engineering faculty members to the academic sector, to recruit larger numbers of new Ph.D.s, and to lead more bachelor-degree recipients into graduate programs.

The recommendations dealing with salaries will not be as easy to implement as many people in the private sector might think. Important institutional constraints exist within universities that make it difficult for them to adjust salaries to meet changing market conditions. One is the sense of equity that pervades salary decisions across disciplines in the academic sector. For example, it is often argued that a faculty member is a faculty member, whether in engineering or English, and each should receive the same salary because the work of teaching and research is essentially similar. Such a view ignores the reality of the marketplace, which means that there is no single labor market for all faculty mem-

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[7] Richard B. Freeman, "Demand for Labor in Non-Profit Markets: University Faculty" in D. Hamermesh (ed.), Labor in Non-Profit Markets, Princeton University Press, Princeton, 1975.

[8] W. Lee Hansen, H. B. Newburger, F. J. Schroeder, D. C. Stapleton, and D. J. Young-Day, "Forecasting the Market for New Ph.D. Economists," American Economic Review, 70 (March 1980).

[9] Charlotte V. Kuh and Roy Radner, Mathematicians in Academia: 1975-2000, A Report to the National Science Foundation, Conference Board of Mathematical Sciences, Washington, D.C., February 1980.

bers but, rather, a whole series of disciplinary-based labor markets, most of which operate independently of each other. In fact, salary differences among disciplines have widened in recent years.[10] Reconciling these two conflicting positions is not easy, and in the meantime, ever larger numbers of engineering faculty members, potential faculty members (new Ph.D.s and graduate students), and even potential graduate students are lured away by highly attractive salary offers.

Faculty salaries also move sluggishly in adapting to changing economic conditions largely because salary increases are set by legislative action rather than by individual colleges and universities, except for private institutions. Were it not for this, it might have been easier in the past few years to divert salary increase money to help retain engineering faculty members (and others in high demand) attracted by outside offers. The reality is that faculty salaries have declined in real terms by about 20 percent during the past decade, and faculty members have been able to do little to arrest this decline.[11] The magnitude of this decline makes it particularly difficult for faculty members in fields whose labor markets are depressed to sympathize with the need to divert already limited funds from salary increases for themselves to salary increases for others whose opportunities have almost always looked more attractive, whether inside or outside the academy.

To conclude, what does this report have to say about the shortage of engineers? It suggests that the labor market for baccalaureate engineers is in rough balance but that this situation is likely to worsen in the future. The report asserts that the labor market for engineering faculty members is extraordinarily tight, and it recommends strong action to alleviate this tightness. But in neither case does it offer much help in understanding more clearly how engineering labormarkets operate.

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[10] American Association of University Professors, "Surprises and Uncertainties," ACADEME: BULLETIN OF THE AAUP, 68 (July-August 1982).

[11] W. Lee Hansen, "The Decline of Real Faculty Salaries in the 1970s," Quarterly Review of Economics and Business, 21 (Winter 1981).

Bureau of Labor Statistics (BLS)

My approach to the BLS study is different; I try to summarize the BLS approach so as to highlight some of the methodological problems, comment on the accuracy of its projections, and examine what the study says about the shortage of engineers.

BLS Methodology

The purpose of the BLS projections is to measure future occupational requirements that reflect as accurately as possible several different sets of assumptions about the future course of the economy. The hope is to enable individuals to make more informed decisions about job choices and the training needed to make those job choices possible. The steps involved in generating estimates of future occupational requirements are long and tenuous. The exercise starts with the production of labor-force projections that are used to develop aggregate economic projections, which are then translated into the national income accounts framework so as to reflect the composition of demand by industry, thereby leading to industry output projections determined with the help of input-output tables. The next step is to develop projections of industry employment that require separately produced estimates of productivity increases. The last step utilizes the industry-occupation matrix to develop projections of employment by occupation.

The estimation chain has many links and it is not clear how solidly forged they are. Each link requires a series of assumptions about the future world and the applicability of past experience in predicting the future. Moreover, all along the way countless judgments are introduced. For example, in using the input-output table to project industry employment, adjustments are made for anticipated technological change and attendant labor-capital substitutions. It is difficult to know exactly how these adjustments are made. It is even more difficult to know whether they are truly exogenous adjustments dictated by the on-going pace of technology or instead reflect at least in part responses to future changes in labor-market conditions and alterations in the relative prices of labor and capital. The basis for adjustments in the industry-occupation matrix to reflect prospective changes in utilization of different types of skills is also unclear; do these adjustments reflect the impact of exogenous factors, or are they too in part endogenous?

Another problem is the failure to develop a more explicit modeling of both the demand and supply sides of the labor market. The term "requirements" suggest a demand-side orientation. Yet projected requirements are taken to reflect what actual employment will be, given the assumptions underlying the projections. This interpretation is substantiated by subsequent comparisons made by BLS between projected requirements for some year and actual employment for that year, with discrepancies being characterized as errors. All this suggests that the various ad hoc adjustments in the input-output coefficients and in the industry-occupation matrix may reflect the implicit introduction of supply-side considerations. It would seem preferable to generate projections of requirements based on unchanged input-output coefficients and an unchanged industry-occupation matrix and then introduce a separate supply model possibly to generate results that, when combined with the requirements model, would produce something that we might describe as reflecting "requirements-supply balance." Whether such a balance would flow out of the interaction of the requirements and supply models is not apparent; they might have to be forced to produce such a balance.

On Shortages

As I understand it, the BLS occupational requirements projections can tell us little about past, present, or potential shortages.[12] The use of some base year for making the projections implies that neither shortages or surpluses existed at that time; while this may be the case for many occupations, it is unlikely that every occupation is in perfect balance in the base year. Hence, the base year may include some imbalance that might be expected to work itself out in the future; how this will be worked out is not clear. The projected values are not much more helpful. If they are estimates of require-

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[12] This is in contrast to other BLS reports. See Douglas Braddock, "The Job Market for Engineers: Recent Conditions and Future Prospects," Occupational Outlook Quarterly, Summer 1983.

ments, there is no comparable information on available projected supplies of workers. Consequently, there can be no disparity that would indicate a shortfall or an excess of workers in a particular occupation. If the projected values are for actual employment, given the assumptions underlying the projections, then they reflect the working out through the labor market of differences in the underlying requirements and supplies so that by definition we can learn nothing about shortages or surpluses.

Accuracy of the BLS Projections

As already mentioned, the projections are evaluated regularly. The results of such evaluations, while of interest, prove to be of minimal value because the methodology of the BLS projections is constantly evolving. Thus, the methodology used to make projections a decade or more ago may bear little correspondence to that employed today. It would be ironic if earlier projections were found to be consistently on target, because the method that had been used to generate such projections would most likely have been altered, making whatever knowledge was gained of only limited historical value.

How accurate are the BLS projections? At the moment we have no way of knowing. The recently published 1995 projections[13] for the major categories of engineers, shown in Table 2, indicate relatively large percentage gains; indeed, electrical engineers and mechanical engineers are listed among the 20 occupational groups expected to grow most rapidly over the period 1979 (the benchmark year for these projections) and 1995, with gains of 65 and 52 percent, respectively, based on the moderate trend projection. These gains compare with an increase of 31 percent for all professional occupations. The report describing these projections gives no indication, however, about whether this growth can be achieved or is likely to be achieved.

One way of learning more about the potential accuracy of the BLS projections is to compare them with the actual

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[13] George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review, November 1983.

TABLE 2. Projections of Occupational Requirements for 1995 for Engineers by Type

Occupational Group	Actual Employment 1982	Projected Employment 1995	Percentage Change
Aeronautical	44	62	41
Chemical	56	80	43
Civil	156	228	47
Electrical	320	528	65
Industrial	160	227	42
Mechanical	209	318	52
Petroleum	26	32	22
All Engineers	1,204	1,788	49

SOURCE: George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review, November 1983, Table 1, p. 38.

employment levels that were realized. Such comparisons can be made for the 1975 and 1980 occupational projections, drawing on two recent evaluations by the Bureau of Labor Statistics.[14] The results for several selected types of engineers appear in Table 3, which shows base year employment in the first column, projected employment in the second column, and actual realized employment in the third column. If we think of these projections as most useful for indicating changes in the size of occupational groups, then as noted earlier we must compare projected and actual employment changes, as shown in the fourth column. The percentage errors appear in the right-hand column. We find that the errors in these projections--for aeronautical, civil, and mechanical engineers--all exceed 100 percent; only two are less than 200 percent! This is not an impressive record. It remains unclear whether the errors, as I have termed them, resulted from faulty assumptions about the economy, inadequate data, or other slips in the chain of steps required to generate the projections.

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[14] Bureau of Labor Statistics, "The U.S. Economy in 1995," Monthly Labor Review, November 1983.

TABLE 3. Evaluation of Projected Requirements for Selected Types of Engineers for 1975 and 1980

	1975 Projections (in thousands)				
Type of Engineer	Actual Employment 1960	Projected Requirements 1975	Actual Employment 1975	Changes in Projected vs Actual	Percentage Error
Aeronautical	46	68	52	22/6	266
Civil	146	248	160	102/14	629
Mechanical	154	255	200	101/46	120

	1980 Projections (in thousands)				
Type of Engineer	Actual Employment 1970	Projected Requirements 1980	Actual Employment 1980	Changes in Projected vs Actual	Percentage Error
Aeronautical	64	77	64	13/0	Infinite
Civil	180	236	192	56/12	367
Mechanical	207	277	232	70/25	180

SOURCES: 1975: Max L. Carey, "Evaluating the 1975 Projections of Occupational Employment," Monthly Labor Review, June 1981, Table 2, p. 15. 1980: Max L. Carey and Kevin Kasunic, "Evaluating the 1980 Projections of Occupational Employment," Monthly Labor Review, July 1982, Table 2, p. 26.

Whether the projections for 1995 will be closer to the mark cannot yet be ascertained. There is certainly no evidence that the two sets of projections just reviewed led large additional numbers of young people to seek engineering degrees so they would be available to fill the many job openings that had been projected. Nor is it clear that in 1975 or 1980 there were many engineers who had been forced to move into other lines of work because of the absence of engineering jobs. Obviously, it would be helpful to explore why these developments did not occur.

Summary

It appears that the BLS projections of engineers can throw little or no light on the question of whether there has been, is, soon will be, or ever (in 1995) will be a shortage of engineers. Moreover, the conceptual fuzziness of these projections strikes me as greater now than before I began this exploration. Even if this is not a matter of concern, the errors pointed out in the evaluations of two sets of projections appreciably weaken my confidence in the accuracy of any employment projections for the future.

National Science Foundation (NSF)

The Vanski paper and the several NSF-contracted studies on which it rests provide a clearer basis than any of the other three reports for assessing the existence of prospective shortages of engineers. This is accomplished by adding a supply side to what I would describe as a demand-requirements model, analogous to that of the BLS. The supply-side model allows a one-round market adjustment process to deal with whatever labor-market imbalances are projected to exist in an occupation after allowing for the entry of people newly trained for that occupation. The market adjustment process proceeds through interoccupational movement by experienced workers and through field-switching (entering a particular occupation after having been trained in another field to enter some other occupation) for newly trained labor-force entrants.

This approach represents a major advance in our ability to analyze shortages because it tries to show how projected employment growth is accommodated on the supply side. Unfortunately, the Vanski paper is sketchy on the details of modeling the supply-side adjustments, on the methods used to estimate these adjustments, and on the empirical estimates on which her reported results are based. Because of this difficulty, I sought out a copy of the DauffenBach-Fiorito paper[15] in hopes that it would provide additional detail. While clearly quite informative in communicating a more detailed understanding of the underlying research, the paper does not present many of the key empirical results or the equations underlying them. Apparently, full details on the various components of the model and the empirical results will become available in the project's final report, which will be submitted soon to NSF. Given the glimpse of what is to come, the final report will be awaited with great anticipation. In the meantime, one can best raise questions rather than offer explicit criticism of the NSF approach.

Methodological Issues

Occupational employment requirements in the NSF model come out of the Defense Interindustry Forecasting System (DIFS), which was built to examine the impact of increased defense spending.[16] The details of this model were not available, but from the little information provided, it appears that the DIFS model generates projected employment by occupation in much the same way as the BLS model. What we don't know is whether similar adjustments are made in the input-output coefficients and the industry-occupation matrix and whether the adjustments could reflect endogenous adjustments to available labor supply.

One would think that the DIFS model would focus on projecting employment requirements--"the amounts of labor that would be required"--to meet different levels of defense and nondefense spending. The key question is

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[15] Robert C. DauffenBach and Jack Fiorito, Projections of Supply of Scientists and Engineers To Meet Defense and Nondefense Requirements, 1981-87: A Report to the National Science Foundation, Oklahoma State University, Stillwater, April 1983.

[16] Department of Defense, Office of the Secretary of Defense, Defense Economic Impact Modeling System, U.S. Government Printing Office, Washington, D.C., July 1982.

whether and how such levels of output could be met, given projections of available supplies of labor and capital. It is quite conceivable that demand growth could be constrained by bottlenecks, actual or anticipated. Inadequate supplies of capital equipment could limit expansion of output and thus hold down on projected employment growth. Or inadequate supplies of trained workers could prevent employment from rising to the projected levels. Thus, it would seem to have been more illuminating to have modeled these projected bottlenecks so as to show projected levels of employment both in the absence of these bottlenecks and with them. Thus, we would have two sets of projected occupational requirements, one unconstrained and the other affected by, among other considerations, the expected supply of labor. In other words, the level of demand would be some compromise between the unconstrained demand for labor and the expected supply of labor, with the latter taken as given; this is the opposite of the NSF model. Alternatively, available supply could still be predicted on the flow of new entrants and some interoccupational mobility, but the full burden of adjustment would not rest on the supply side alone.

The NSF model takes projected employment by occupation as given and then proceeds to estimate the initial level of shortage or surplus as the disparity between projected employment and the inflow of new entrants freshly trained for that particular occupation. To the extent that supply falls short of employment, the gap is taken up, to a greater or lesser extent, by interoccupational shifts as experienced workers enter the occupation from related occupations and by field-switching as newly trained job entrants enter the shortage occupation even though they did not train directly for that occupation.

The process that determines the size of the adjustments to labor-market imbalances in the NSF model is not clearly indicated. As the model appears to operate, it is the size of the imbalance that governs the magnitude of the response. It takes more than imbalances, however, to induce any substantial movement among occupations or to attract new entrants trained in other fields. Given the sensitivity of starting salaries to changing supply-demand conditions, as reflected in labor-market imbalances, something else is going on that is not made explicit in the model. Perhaps there is intensified recruitment activity, reduced duration of transitional unemployment, better fringe benefits and working conditions--all of these can facilitate adjustments.

If, on the other hand, the system is relatively effective in adjusting to labor-market imbalances, why would we expect to find some labor-market imbalances not being resolved over the five-year span of the NSF projections? Is five years too short a period? If so, what determines the time required for a labor-market imbalance to be eliminated? In light of these questions, I would prefer a more explicit modeling of the forces that help to determine the magnitude of the supply-side responses.

Some clues might emerge if more attention could be given to the sequence of actions over the five-year interval leading up to the 1987 projection year. Is there some kind of an annual playing out of the script for labor-market imbalances? Or does some interactive process operate that for simplification is assumed to reflect perfect foresight among workers and potential workers? What if individuals make miscalculations on some large scale? These could result in overshooting or undershooting the projected levels, depending upon how we might model the adjustment process. Would it be possible, therefore, to model the time-adjustment paths that help to resolve initially projected labor-market imbalances?

That we do not know much about the adjustment process is revealed by the following example of what could result from publication of the BLS projection for 1995; as noted earlier, this projection shows substantial increases in employment for most types of engineers. Suppose young people and their parents read these projections in the Occupational Outlook Handbook and interpret them as evidence of a possible shortage of engineers. As a result, parents encourage their high school senior children to think about majoring in engineering. Many students will, no doubt, follow this lead. But other more astute high school seniors will think along the following lines: if everyone decides to go into engineering, there could be a substantial surplus of people vying for jobs four years from now, and so it may be wise for me to enter another field, perhaps one that potential engineering students would have entered otherwise. But the many, fewer really astute high school seniors, after tracing through the process, see the flaw, namely that a number of other students may realize what the astute high school senior recognized, causing them to flow into the alternative occupation. But our few super astute high school seniors come to a decision to enter engineering after all, believing that they will outsmart their peers in the end and gain from a favorable labor-market imbalance. This is a kind of "rational expectations" version of labor-market adjustments.

I would much prefer a model that allowed for simultaneous and explicit adjustments on both the supply and demand sides of the market. This is obviously a more complex task, but one that reflects more clearly the way labor markets operate. Individual employers may be frustrated in their desires to hire additional people in an occupation, just as individuals may be frustrated in their desire to enter particular occupations. We must recognize, however, that changing perceptions of present and future labor markets will affect future labor-market balances. To settle on an employment total without allowing for the possibility that output, and hence the level of expected employment, may have to give because of constraints on supply leaves out one of the essential features of labor markets as we know them.

Is There A Shortage?

How does this report come out on the question of engineer shortages? Based on its analysis of the 1982-1987 period, shortages are likely for aeronautical engineers and computer specialists, and a potential shortage of electrical engineers could develop; labor-market balance will exist for the other groups of engineers. These conclusions may be comforting, but they rest almost completely on the supply adjustment model about which we yet know too little. The tremendous power of that model is revealed in comparing labor-market balances as a percent of supply in Table 4 of the NSF paper for supply adjustments with and without occupational mobility. With mobility, none of the labor-market balances exceed 6 percent of total supply. Without mobility, labor-market balances as a percent of supply are below 7 percent for only one of the occupations shown. This difference suggests a possible circularity, namely that the size of labor-market adjustments as they are defined here are closely keyed to the initial imbalances. In other words, adjustments almost by definition wipe out imbalances except perhaps for some small error component. This seems too good to be true.

To sum up, the jury is still out. Moreover, further comments on the NSF paper must be deferred until the full report becomes available. What we see in this model is a move in the right direction, a move that we hope will motivate others to work more intensively so as to achieve a better understanding of how labor-market balances are achieved.

Conclusions

Whether an engineer shortage exists now or is likely to exist in the near future is perhaps no clearer now than it was before I received these papers. The American Electronics Association offers evidence that is mixed as to whether there is or is not a shortage now but indicates that with a strong pickup in economic activity there could be a general shortage. The American Council on Education study suggests that a balance currently exists in the labor market for engineers, with the probability of some shortages over the next five years or so (the ACE study takes as given the shortage of engineering faculty without offering any direct evidence on the point). The BLS study provides no help because it looks only at projected requirements in 1995, saying nothing about prospective supply and potential imbalances between prospective demand and supply in the interim. The National Science Foundation study starts with the premise that there is a current balance, and it goes on to suggest that engineer shortages are likely to be confined to one or two sectors over the period 1982-1987. The only real agreement among the studies was pointed out by Mike Mandel--namely, that the annual rates of projected employment growth for engineers are fairly similar across all of the reports--but this is deceptive because three of the reports use highly similar measurement approaches.

If the answer is inconclusive, that is what we must live with. At the same time I believe we have learned a great deal from these papers. One is that care must be exercised in reporting the results of surveys and trying not to extract too much out of them while at the same time indicating the need for a more probing examination of the survey results. Another is that the record of accuracy for employment projections leaves much to be desired, and therefore we should not rely too heavily on what may be a weak foundation for assessing future labor-market imbalances. Still another is that the possibility of supply adjustments through interoccupational mobility represents an important forward step in assessing labor-market imbalances; that we may need to incorporate similar demand-side adjustments to reflect employer adaptation to projected labor-market imbalances via changes in technology, alterations in capital-labor ratios, and substitution of one type of labor for another; and above all, that we must model both the supply and demand sides of the labor market. Only in this way can we understand what lies behind and determines the projected outcomes and associated labor-market imbalances--the patterns of adjustment, who does the adjusting, and what motivates it.

In conclusion, let me propose another meeting like this in 1994 to assess what we have learned in our quest for more accurate perceptions of future labor-market conditions.

COMPARATIVE ASSESSMENT

Michael Mandel
Harvard University

The four studies presented at this symposium have arrived at different--and sometimes diametrically opposed--conclusions about whether shortages of engineers are likely in the coming years. Surprisingly, these disagreements do not reflect different supply and demand projections. I will therefore focus my comments on identifying the similarities among the scenarios and understanding how they could have come to different conclusions. In addition, I will discuss some alternative ways of thinking about shortages.

First, consider the demand for new engineers (in thousands) over the next five years, as projected by the Bureau of Labor Statistics (BLS), National Science Foundation (NSF), and American Electronics Association (AEA):

Projection	Demand (x 1,000)
BLS (moderate scenario)	45
NSF	
stag low	32
optim/high	60
AEA	48

The AEA estimate was obtained by multiplying the projected job growth reported by survey respondents by three, since the responding companies represented about one-third of the U.S. electronics industry (this is the same procedure that the AEA uses to project growth in its study).

Note that if the high and low NSF projections are averaged, all three studies project almost identical growth in the total number of engineers over the next five years. This is true even for the AEA study, which used a much different methodology than the other two. (It bears mention, though, that the AEA study focused only on the electronics industry, broadly defined--including aerospace, telecommunications, and software services. Growth in the number of engineers in other industries, therefore, is not included in the AEA projections).

Similarly, the three studies yield quite close estimates of future demand for electrical engineers (in thousands):

Projection	Demand (x 1,000)
BLS (moderate scenario)	90
NSF (optim/high scenario)	90
AEA	96

The BLS estimate is obtained by taking their 1995 projection and assuming that growth proceeds smoothly over that period. As before, the AEA estimate is calculated by scaling up their survey results by a factor of three.

It is clear that the gross demand projections of the three studies do not vary appreciably. The same statement holds for the supply projections for engineering graduates as well. When the AEA study compares its demand projections for electrical engineers (EE) to their supply projections, they find that about one-third of new EE jobs cannot be filled by new EE graduates. The NSF study reaches the same conclusion--that without taking interoccupational mobility into account, one-third of new EE jobs cannot be filled by new EE graduates. Therefore, the AEA predicts the annual shortfall of EEs to be 6-10 thousand annually (depending on whether defense contracts are included), while the NSF predicts a shortfall of 7,000 annually.

Given that their supply and demand projections are so similar, why do the AEA and NSF studies arrive at such different conclusions? The AEA study assumes that the supply of people qualified to take new EE jobs is restricted to EE degree-holders--specifically, new EE graduates. By contrast, the NSF study allows for occupational mobility and reentrants into the labor force. When these sources of supply are added in, the supply/demand situation for EEs significantly improves.

These alternative sources of supply have rarely been modeled. The NSF-sponsored model for projecting occupational mobility and reentrants (for which Robert DauffenBach and Jack Fiorito are principally responsible) is therefore quite innovative and important. It provides estimates of how many people will switch into electrical engineering from other fields and arrives at the conclusion that electrical engineering has sufficiently high "in-mobility" to ameliorate the shortage problem.

However, in its current form the model has some problems (which the authors, I'm sure, are well aware of). In particular, it is constructed and estimated in such a way that supply and demand will almost always balance. Occupational mobility is more or less treated as a residual category that will usually make up the shortfall between supply and demand. For example, the NSF model (under the optim/high assumption) predicts that the net in-mobility to electrical engineering in 1985 will be 8,000. Since the AEA study projected the shortage of EEs to be on the order of 6-10 thousand, it is clear that the net mobility is on the same order as the shortage and, therefore, accounts for the difference in conclusions.

However, even accepting the conclusions of the NSF model--that there will be a rough balance between supply and demand in almost every engineering category--leaves us with a problem. The AEA survey showed that at least half of its respondents anticipated a shortage of EEs, either currently or in the near future as the economy improved. It is inappropriate to write these fears off as mere misperceptions, since the respondents are reacting to real features of the electrical engineering labor market. Instead, we must ask if comparing gross supply and demand numbers provides an accurate measure of whether a shortage exists.

Defining a shortage as "demand minus supply" is appropriate if supply and demand are independent of each other. However, if supply and demand can adjust to narrow the gap (as happens in the NSF model), then it is necessary to think about shortages in other ways. In particular, we will briefly consider here three ways that "shortages" can occur, even when supply and demand balance: (1) quality-related shortages, (2) search-related shortages, and (3) turnover-related shortages.

The quality issue has been discussed by several other symposium participants. If personnel outside electrical engineering are needed to fill electrical engineering jobs, there may be a quality drop-off, which is difficult to measure but present nevertheless. Even if there is no quality problem today, the available pool of qualified personnel who can transfer from other occupations may be finite, so that high rates of in-mobility into electrical engineering are not indefinitely sustainable. (On the other hand, it may be possible to rearrange work so that not as many electrical engineers are needed.)

A search-related shortage occurs when a employer has to engage in a longer and more expensive search process to find the right person for the job. In particular, if an employer has to draw on personnel not in electrical engineering to fill electrical engineering jobs, it will be harder to identify qualified people and harder to evaluate them. When the search process takes longer, the number of vacancies will typically increase, even if supply and demand remain balanced. In addition, the out-of-pocket search costs will rise (and these are not insignificant, being often on the order of a year's salary). Note also that the quality issue can aggravate a search-related shortage, since as the pools of easily identifiable qualified labor are exhausted, the search process will take longer.

There is also a third type of shortage, which appears to be related to the high turnover rates found in some skilled occupations. The high turnover rates lead to a breakdown of normal career paths and internal labor markets, in the sense that short-term employment relationships are common and that experienced engineers have been often hired on the spot market on a project-by-project basis.

As a result, the labor market for engineers displays some anomalous features. On the one hand, as Mr. Kutscher mentioned, wages for inexperienced engineers have been rising relative to wages for comparable professionals, while wages for experienced engineers have not (suggesting that inexperienced engineers are in short supply relative to experienced engineers). On the other hand, small electronics firms, at least in Massachusetts, complain of a shortage of experienced engineers.

One possible explanation for these observations is that high turnover and the constant need to hire from outside the firm leave the firm without the ability to offer some incentives to its young engineers, such as promotions and long-term security. Instead, it is obligated to pay higher wages immediately. This makes experienced engineers cheap relative to inexperienced ones, but the supply of experienced engineers is completely inelastic in the short- and medium-term, being effectively determined by the number of gradutes 5-10 years earlier. All told, companies can end up paying more for labor than if they could bring up sufficient numbers of experienced engineers within the company.

These three types of shortage can all occur even when supply equals demand. It would be useful, therefore, to look beyond the aggregate numbers to the more detailed workings of the labor market for engineers to determine if there really is a "shortage" problem. The needed data will not be readily available--mobility rates, vacancy rates, and wage rates, for example--on a detailed occupation by industry basis. However, it is important to keep these possibilities in mind when thinking about the effects of shortages.

DATA ISSUES

Harold Wool
Independent consultant

In my comments I will discuss three empirical data issues relevant to the assessment of current and projective labor-market conditions in the various engineering fields:

(1) The adequacy of the available data base for measurement of current supply-demand imbalances,
(2) The uses and limitations of the employer survey technique, and
(3) The limitations of the available data base for measurement of the occupational mobility component of engineering labor supply.

To the extent that there are differences in judgments concerning the existence of current shortages in various engineering fields, these may be traced--at least in part--to the limitations of current measures of occupational supply and demand. The supply of workers for a given occupation may be defined as the sum of those currently employed and of qualified persons seeking work in that field. The demand for workers, in turn, is the sum of occupied positions, i.e., employment, and of vacant positions that employers are seeking to fill, at prevailing wages. Since employment is a common component of both supply and demand under this formulation, a simplified form of this relationship is the ratio of job seekers to job vacancies.

Although there is, I believe, general agreement on this conceptual formulation, we unfortunately do not have adequate data to apply this concept rigorously in analysis of occupational labor markets. On the supply side, the unemployment rates by occupation, based on the Current Population Survey (CPS), are limited to experienced workers only, i.e., those with a previous full-time job, and classify such workers by the occupation of this previous job. Thus, recent engineering graduates seeking their first regular jobs are excluded by definition from the unemployment count for engineers.

On the demand side, our current information system is even more deficient. We have, at present, no comprehensive data on job vacancies in this country. A job vacancy statistics program, initiated by the BLS in the late 1960s, was abandoned after a few years because of a combination of technical and budgetary difficulties. Partial data on unfilled job openings at public employment offices are available, but they are of little or no analytical value, particularly in the case of professional occupations, because of the limited role of the public employment offices in filling jobs in these fields.

As a practical matter, we are forced to rely on a combination of partial indicators for any analysis of occupational labor markets. These include CPS data on employment trends and on unemployment rates for experienced workers, as well as data on earnings or salaries, available from a variety of sources. Considerable supplementary data are also provided by NSF-funded follow-up surveys of recent degree recipients in scientific and engineering occupations, as well as by two recent sample surveys of a panel of a few hundred employers. These sources have, in combination, provided us with much useful information on trends in the various major scientific and engineering fields. However, it is easy to appreciate that--because of differences in scope, timing, and reliability--the results are subject to differing interpretations concerning the existence and severity of shortage problems in specific engineering occupations.

Shifting our time focus from historical to prospective trends, two approaches to forecasting of occupational demands have been illustrated by the papers presented here today. The methodology used by the BLS and the NSF, deriving from national econometric models, has been thoroughly documented and critiqued, based on the track records of such projections over a considerable time span. I will therefore not attempt to repeat, here, the strengths and limitations of the "top-down" approach to forecasting of occupational employment. An alternative approach is illustrated by Pat Hubbard's paper, presenting projections based on a recent survey of firms in the electronics industry. This approach is deceptively attractive, since employers would appear to be the logical source of expert knowledge on their own employment plans. However, experience with such surveys ever since World War II has indicated that they tend to result in overstatements of industry-wide employment needs, stemming in part from a tendency of respondents to project that their companies will all enjoy a greater share of the industry's total market. Moreover, as indicated by the AEA survey results, non-response rates tend to be unacceptably high in such surveys, since most small and medium-sized firms do not engage in manpower planning and have limited capability for making informed projections of their employment needs, particularly for period of two or more years in the future.

Despite these limitations, I would like to stress that well-designed employer surveys can play an important role in any comprehensive information system on occupational labor markets. The primary time focus should be, however, on recent and current employment experience, possibly supplemented by data on short-term hiring plans, for periods of no more than six months ahead. In addition to the obvious data on employment and job vacancies, these surveys could help fill an important information gap on the qualitative aspects of occupational labor markets by identifying employer hiring standards in terms of such criteria as types of degrees held, type of institution attended, class ranking, etc., and by indicating the extent to which actual recruits satisfied, or exceeded, those standards. I would also like to see more systematic probing on the impacts of reported shortages, including such possible effects as reduced productivity, increased labor costs, or inability to meet production or R&D schedules. The recently initiated NSF "quick response" employer survey program may provide a useful vehicle for developing this type of information, with respect to scientific and engineering occupations.

Turning now to the supply side of the equation, I would like, first, to compliment the NSF staff and the "DFF" team of researchers (DauffenBach, Fiorito, and Folk) for their pioneering efforts in development and application of a comprehensive model of supply of scientists and engineers. Although the major elements of the labor supply in these professions have been well defined in previous studies, this model is--to my knowledge--the first systematic effort to integrate the various types of supply flows into a dynamic model that is also responsive to changes in occupational demand. In any further development of the model, I would suggest (1) inclusion of an explicit occupational wage variable and (2) inclusion of a feedback mechanism that would simulate adjustments on the demand side (i.e., employment) resulting from shortage-induced increases in occupational wages.

The most critical problem in any approach to forecasting engineering labor supply is not, however, in model design, but in the limited available empirical data on occupational mobility of engineers, including entrants or reentrants into engineering of persons last employed in non-engineering occupations as well as recent graduates with non-engineering degrees who have been hired as engineers. These sources have, in combination, accounted for as much as one-half of the gross flows into engineering under some of the estimates presented to us. Yet, the data base available for projecting future occupational mobility is so limited that BLS, as well as other forecasters, have either refrained from any explicit estimates of these flows or have assumed that gross and net occupational transfers are constant functions, hence limiting the "action" on the supply side to variations in the number of new engineering graduates. I consider these assumptions to be unrealistic: first, the supply of qualified, or semi-qualified, "reserves" available for transfer to engineering is finite. Hence, any rate of inflow based on experience during periods of high engineering demand may not be sustainable. More generally, it is reasonable to expect that these flows will vary in relation to changing labor-market conditions because they are likely to be the sources of recruitment of "last resort," when the supply of fully qualified engineers is inadequate.

In recognition of this logic, the "DFF" team attempted to develop an occupational transfer variable as a function of projected demands. As noted in their detailed report, their efforts in this respect were not very successful. It is likely that one source of their difficulties was the very limited data available for analysis of occupational transfers into S & E occupations. This consisted of three CPS retrospective surveys--conducted in January 1973, 1978, and 1981--designed to identify who had changed occupations during the preceding 12-month period. Clearly, a sample of only three periods is insufficient to measure sensitivity of occupational mobility rates to changing labor-market conditions. Moreover, the CPS occupational entry data derived from these surveys include as occupational transfers persons who were both employed (in non-engineering jobs) and enrolled in school in the base period and who entered engineering employment in the following year after having received a degree in engineering or in some related field. At a minimum this suggests the need for a careful disaggregation of the existing data base, in order to more specifically classify entrants into engineering jobs by educational qualifications, prior employment, and other relevant characteristics. In the long run, I would suggest that expansion and refinement of the existing stock of data on occupational mobility may be the most cost-effective approach to improving the reliability of labor-market projections in engineering, as well as other professional occupations.

SUMMARIES OF AFTERNOON SESSIONS

PANEL A
FACULTY SHORTAGES IN ENGINEERING DEPARTMENTS

Presentations

Daniel DRUCKER of the College of Engineering, University of Illinois-Urbana, opened the session with a strong statement that faculty shortages in university engineering departments pose severe problems across the country. Departments are increasingly dependent on hold-over retirees who will soon leave the system entirely, part-time personnel chosen more for their availability than for their expertise, and Ph.D.s whose undergraduate standing was below the top 10 percent of their class. DRUCKER cited a statement by the dean of engineering at the University of Washington that the engineering college "has replaced only about half of its recent faculty losses" and one by Dean J. Charles Jennett of Clemson University that "the College of Engineering now teaches the largest junior and senior courses at Clemson University and, strangely, the situation is becoming worse. . . . The College receives [from the state] only a fraction of the funds required to sustain quality." The concern, DRUCKER stressed, is fundamentally about quality: not enough of the top-quality engineering undergraduates are pursuing the Ph.D. and, of those, the fraction who would like to teach has been declining. That is the source of the faculty shortage.

Samuel HULBERT, President of Rose-Hulman Institute of Technology, described the faculty shortage as it is experienced at Rose-Hulman, a highly selective, predominantly undergraduate engineering institution with a total enrollment of 1300 students. HULBERT reported a rapid shift of undergraduate enrollments toward computer science and electrical engineering. Just over a quarter of the students majored in those fields in 1978, while more than half are expected to do so next year. A similar trend in enrollments is evident at other schools as well. In response to this demand, Rose-Hulman has expanded its electrical engineering and computer science faculty from eight to eighteen during the past six years, but anticipates three vacancies in the coming year. Most hires in these fields have come from personal contacts, including the hiring of four Rose-Hulman alumni, rather than advertising. In other fields, including chemical and mechanical engineering, recruiting of new faculty through the normal channels is much easier.

HULBERT noted that half to three-quarters of all job applications for his faculty are from foreign-born engineers. Despite the advantages of foreign-born faculty in providing a broadening experience for students, there are real limitations in their communication skills.

In the short-term, Rose-Hulman will try to deal with its faculty shortage problems by employing faculty from other departments in the teaching of electrical engineering and computer science courses, by encouraging more students with an interest in computers to major in fields other than electrical engineering that also call for computer applications, and by hiring visiting instructors.

HULBERT concluded by arguing that as a faculty shortage continues over a sustained period of time, its effects become more severe. Heavy teaching demands on available faculty reduce the amount of scholarly activity on campuses and in the long run reduce the quality of the faculty. The fact that the shortage has continued so long is beginning to affect the overall quality of U.S. engineering education.

Edward LEAR, executive director of the American Society for Engineering Education, drew on the results of the Engineering Faculty Shortage Project, a joint study by the ASEE and the American Association of Engineering Societies, to document the faculty shortage. He suggested that data indicating an overall faculty shortage in engineering of about 8 percent understate the problem because administrators will not authorize positions, even if they are needed, if there is no prospect of their being filled. If deans are asked how many faculty are really needed, rather than how many positions they are currently willing to authorize, the implied shortage would be about 20-25 percent, instead of 8-10 percent.

A different way of estimating the shortage is to compare increases in numbers of engineering students to increases in the faculty available to teach them. Such a comparison indicates that to restore the ratio of faculty to students that prevailed in the late 1960s would require an addition of about 6,000 faculty in the engineering colleges. Even if it would be appropriate to cut this figure in half, allowing for greater efficiency in teaching now than in the late 1960s, that figure still, in Lear's view, indicates a very serious shortage.

LEAR noted that several recommendations of the Faculty Shortage Project have been acted upon, including some good industry stipends for graduate students, some attractive government scholarships, and the NSF's new Young Faculty Investigator Program, but that a great deal more needs to be done. Prospects for the immediate future are worrisome, since the output of U.S. Ph.D.s has fallen by almost a thousand from its 1972 high of 3,700 (and indeed the falloff in U.S. citizen Ph.D.s is even greater since the number of foreign nationals getting U.S. Ph.D.s in engineering has risen slightly over that period). LEAR reported that an analysis by Bob ARMSTRONG of Dupont of the Ph.D. pipeline points toward some increase in the number of Ph.D.s being produced in the near future. However, the increase in the pool of young faculty will be almost entirely foreign nationals. Many of these are highly talented people, but owing to language capability, availability for jobs, and other factors, they are not a pool it is safe to count on.

Fred LANDIS of the University of Wisconsin-Milwaukee brought further evidence to bear on the quality issue by citing data from 29 member institutions of the National Association of State Universities and Land-Grant Colleges that are among the major producers of engineers. These data indicate that over the period 1975-1976 through 1980-1981, the increase in the student population in engineering was much greater than the increase in faculty (43 percent vs. 7.9 percent). The student-faculty ratio has moved over that period from a desirable ratio, on a national basis, of about 12 to 1 (after adjusting for faculty research commitments) to one of more than 16 to 1. To restore the ratio that prevailed in 1975-1976 on a national basis would require 6,000-7,000 more engineers, thus corroborating Edward Lear's calculation.

In LANDIS' view, nothing of significance has been done over the last four years to alleviate the faculty shortage. Minimal efforts by the federal government, along with efforts by selected industries and a few states, to support engineering education are inadequate. Moreover, in Landis' assessment, the problem will not go away on its own. His assessment is that engineering enrollments, and therefore requirements for faculty, will continue strong even if, as is not unlikely, some softening of the engineering job market occurs. This is partly because the job prospects outside engineering are expected to remain relatively unfavorable and partly because the high innate ability of recent engineering graduates has made industry more receptive to employing engineers in a wider variety of business-oriented ways.

LANDIS concluded by urging that a solution to the faculty shortage problem will require raising faculty salaries to levels competitive with industry and restoring the relative advantage of Ph.D. and master's salary levels over bachelor's levels. LANDIS cited figures indicating that these salary differentials had fallen significantly in constant dollar terms since 1967--in the case of Ph.D.s, from $500 more than B.A.s to only $300-$350 more. He asserted that it is up to university presidents and boards of regents to face up to the need for better pay and working conditions for engineering faculty.

David REYES-GUERRA, executive director of the Accreditation Board for Engineering and Technology, opened his remarks by suggesting a possible lesson in the increasing tendency for industry to undertake its own graduate instruction. Perhaps this is an indication, he proposed, that it would be useful to distinguish more sharply the task of transmitting knowledge to undergraduates from the task of creating new knowledge that is associated with graduate study. He suggested that engineering schools may not be doing the knowledge transmission job as well as they should, partly because faculty divide their efforts between knowledge transmission and research and partly because foreign graduate assistants with a weak command of English may be poorly equipped for this task of transmitting knowledge.

In reporting on the accreditation work his organzition performs, REYES-GUERRA indicated that a decreasing proportion of engineering schools are receiving a full six-year accreditation, while more are being approved for only a three-year accreditation, after which a revisit is required. The most frequent sources of deviations from the miminal criteria for accreditation were, in order of occurrence, curriculum, faculty, and facilities and academic support.

REYES-GUERRA cited data on changes in various indicators at engineering colleges between 1982 and 1983, showing very rapid increases in captial expenditures per faculty member and in computer expenditures per student. These expenditures reflect both the efforts of engineering colleges to deal with the problem of obsolescence of equipment and the need to make strong efforts to stay abreast of developments in computing. Data on faculty salaries have to be judged carefully, since they are nine-month data and do not include outside compensation. From 1980 to 1983 full professors' salaries increased 30 percent, associate professors' salaries increased 33 percent, and assistant professors' salaries increased 40 percent. Despite the more rapid rise in percentage terms in assistant professors' salaries, REYES-GUERRA stressed that the number of dollars by which those salaries grew is not very impressive, since the base is relatively low.

Percentages of foreign students in engineering have stayed remarkably steady over the last thirty years, at between 22 and 23 percent, and the percentage of foreign students in graduate school is actually lower now than it was ten, twenty, or thirty years ago. Nonetheless, these constant percentages may be misleading, since the actual numbers of foreign undergraduate and graduate students have grown quite rapidly over the last three decades, increasing approximately tenfold.

Discussion

Daniel DRUCKER opened the discussion by sketching a simplified steady-state analysis showing that with a total engineering faculty of approximately 20,000, about 1,000 new faculty per year (5 percent of the total) would be needed to replace faculty who leave for industry, retire, or die. With 2,700 new Ph.D.s produced per year, DRUCKER estimates that about one-third are qualified to teach and of those qualified about one-third desire to teach. Thus, the steady-state supply of new Ph.D.s to teaching is about 300, while the steady-state requirement for new faculty--which is smaller than the actual current requirement because there is growth in demand for engineering faculty--is about 1,000. DRUCKER estimates that if it takes ten years to deal with this problem, it will kill the quality of at least half of the engineering schools in the country.

Joseph SHERIDAN, executive director of the Engineering Manpower Commission, raised two questions suggesting that there might be indications that the situation in academia is improving. The first was evidence that recent figures indicate that more engineers are leaving industry for academic jobs than are leaving academic jobs for industry, suggesting that academic employment is becoming more attractive. The second was the information from David **REYES-GUERRA** that faculty salaries were rising by 7 to 10 percent per year while other engineers are receiving raises on the order of 2.8 percent. This too might indicate that difficulties in hiring faculty are being reduced.

Fred **LANDIS** replied to both points. Regarding the flow of engineers from industry to academic jobs, **LANDIS** suggested that this was a product of the recent recession and that as the economy recovers, there will again be a net flow of faculty into industry. Regarding salaries, **LANDIS** agreed that there has been an increase in assistant professors' salaries relative to industrial salaries but claimed that it was not an adequate change. He stressed that students examine the career income profiles of engineers in academia versus industry and that the present economic situation of full professors does not make them attractive role models for young people.

Paul **DOIGAN** of General Electric Company inquired of Sam Hulbert whether his institution required the Ph.D. of all new faculty, since failure to hire Ph.D.s might be a source of some of the accreditation problems that David Reyes-Guerra described. **HULBERT** replied that most of Rose-Hulman's new faculty are Ph.D.s, but there is no hard and fast rule against hiring non-Ph.Ds to tenure-track positions. He noted that even at a starting salary of $32,000 to $33,000, it is not possible to find assistant professors in computer engineering. **DRUCKER** added that at Illinois new faculty will start at $36,000 next year, and that is still not adequate to attract the highest-quality people away from industry.

Charlotte **KUH** of AT&T, pursued the salary question by asking to what extent academic salaries are supplemented by consulting money. She cited evidence from AT&T that this kind of link between teaching and industry can be symbiotic because it helps to improve the pipeline for students into industry. Daniel **DRUCKER** stated that at his institution, which is highly research-oriented, the average number of days consulting per engineering faculty member is less than ten--a much smaller number than many people think. Robert **WEATHERALL** of Massachusetts Institute of Technology indicated that a survey at MIT of 1967 graduates showed that among those electrical engineering graduates who later got the Ph.D. and joined faculties, they were on average receiving more compensation from all sources than were those in industry. His view is that graduate students are disturbed more by lack of equipment and resources than by salalry differentials. Industry, he suggested, often provides more opportunities for independent research than does academic employment.

William UPTHEGROVE, Regents Professor of Engineering at the University of Oklahoma, followed up on the consulting question by saying that the best available data, to his knowledge, comes from a study done at the Office of Institutional Research at USC about three years ago. They found that on average engineering consulting incomes for faculty at a research institution were on the order of $5,000 to $6,000 for an assistant professor, and under $9,000 for a full professor, with a somewhat higher figure for associate professors. Thus, consulting income is not enough to overcome the real problems of inadequate faculty compensation. Fred LANDIS supported this point by noting his recollection that average full-year total earnings for engineering faculty on a national basis were only about $9,000 per year higher than nine-month base salary. Sam HULBERT added that the problem is not simply financial, but relates to the quality of life issue that Robert Weatherall addressed.

Michael PELCZAR, president of the Council of Graduate Schools in the United States, asked the university representatives to describe their present efforts and future plans for offering education training programs for employed engineers. Daniel DRUCKER agreed that the need for such continuing education was great, but that it was very difficult to find a clientele for it, even when it is made available quite conveniently. Jeanne CARNEY of the Department of Defense noted that electronic teaching arrangements transmitted by satellite to remote locations elicit a very high response. Fred LANDIS pointed out that there are great differences in the kind of continuing education sought by recent graduates, who are more professionally- than company-oriented, and that of the typical person over thirty, who is generally interested in continuing education only if it will improve the ability to perform his or her present job. Sam HULBERT acknowledged the importance of continuing education of engineers working in industry but stressed the importance of the other side as well, of having faculty learn from engineers in industry about important new developments in such fields as computer graphics, CAD/ CAM, and robotics.

Howard P. TUCKMAN, economist of Florida State University, suggested that the group was really saying two very different things. The first was that forecast models should integrate market forces more effectively; the market is in some sense good because it directs resources sensibly. Engineers are drawn to industry because industry has a greater use for them and can supply the capital equipment they need to work with. We know that Ph.D. salaries are falling relative to B.S.- and master's-level salaries. Perhaps the market is making a judgment that the best use of people is not in academia right now. If so, perhaps the group should be discussing how to tap into the most productive people in indsutry for part-time academic work. He asked the panelists to address the lack of integration between these two sets of discussions: the virtues of the market and the negative effects of the market on hiring of Ph.D. faculty.

Daniel **DRUCKER** replied that Tuckman was assuming that the marketplace makes valid intellectual judgments, which Drucker considered a novel proposal. The marketplace may or may not make valid economic judgments, but it is clearly not true that it makes proper intellectual judgments. The nation's present difficulties with elementary-secondary education illustrate this: the marketplace has worked superbly in that we have been paying teachers low salaries and we get what we pay for. But as a result, the country is going downhill. Similarly, at universities we don't pay engineers enough, and we don't have the people. Hence, university education in engineering is going rapidly downhill. This is a national problem and not explicitly and directly the problem of any individual industry. Industry must pull together to help with the faculty problem because doing so is in the collective interest of industry even while it is not in the interest of any one company to do it alone. That is the tragedy of the commons.

One symposium participant added that Tuckman's approach assumes that universities, like industry, are governed by supply and demand. But they are not in the marketplace in that way. Universities are governed by values and laws internal to themselves that impose limits on the range of engineering salaries. Universities thus lack the flexibility to respond to the market as industry does.

Lee **HANSEN**, economist at the University of Wisconsin-Madison, asked when the malaise in academic engineering actually began. He wondered if it really dated from the 1973-1974 period when student-faculty ratios began to rise or whether there has really been a longer-term decline in the quality of work at engineering schools as the focus of new developments has moved, for whatever reason, to industry. HANSEN suggested that the discussion has assumed implicitly that these negative developments have all occurred in the last decade. If that is wrong, then the discussion might want to proceed in quite other terms.

Daniel DRUCKER did not agree with Hansen's suggestion that most fundamental developments occur in industry. It has always been true that the forefront of the practical applications of new technology occur in industry, but the number of fundamental developments that occur there rather than in universities is much smaller than one might expect. The very new development, however, is that the apparatus for exploring the full power of new developments is now in industry. HANSEN countered by suggesting that this trend may be a consequence of the quality of people who have been in engineering schools for a long time, and not simply a problem about the quality of new faculty. DRUCKER replied that the overloading of the faculty that accompanied the increasing numbers of students beginning in the early 1970s has reduced their productivity. HANSEN pointed out that in 1971-1972 enrollments in engineering reached a trough; and universities, including the University of Wisconsin, were trying to figure out what to do with their surplus engineering faculty. There must have been very low student-faculty ratios, which, by Drucker's logic, should have generated a tremendous spurt of research productivity and innovations at that time. DRUCKER replied that at most universities engineering budgets at that time were cut in proportion to enrollment declines, and since 1972 they have not recovered proportionately.

Fred LANDIS noted that in 1971-1972, the student-faculty ratio at the University of Wisconsin-Madison was indeed quite low, below 10 to 1. But he then went on to point out that there are two separate issues at stake in the discussion. First is the continuing overload of faculty, whose effects can be seen in design courses where individual attention to students is essential, and in laboratories, where student participation is increasingly replaced with demonstrations. As a result of this crowding, the value added by universities is falling, but this is not readily recognized in industry because of the high quality of the students who are entering engineering programs today. The second, distinct problem is that capital cost per student for modern education has continually risen, owing to computers, CAD/CAM, and other developments. Universities cannot meet these cost increases either. That is a parallel but basically separate development.

Robert ARMSTRONG, E.I. Dupont de Nemours & Company Inc., noted that the industry point of view is not heavily represented at this meeting and reported on a meeting in December of the continuation of the Faculty Shortage Project at which industry was heavily represented. Armstrong stated that industry does not see a major impact on quality as a result of the rising student-faculty ratio. This may be because of the high intrinsic quality of the entering students, but Armstrong is not convinced of that. He reiterated that they think the students they hire from the engineering colleges are great.

PANEL B
ENGINEERING EMPLOYMENT AT FEDERAL RESEARCH LABORATORIES

Presentations

David BRAUNSTEIN, executive director for special projects at NASA, spoke to the issue of engineer shortages from the Space Agency's perspective. Employment at NASA peaked at 35,000 in 1967 and decreased steadily to the 1984 figure of 22,000. Roughly one-half of NASA employees are engineers with between 400 and 500 engineers hired by NASA annually. Turnover at the agency for engineers is very slight, between 4 and 5 percent per year. In 1983, NASA made a strong effort to hire engineers, in part because of concern about an aging work force. They seized upon the opportunity of a relatively weak job market and hired 600 new engineering graduates, 39 percent of whom were women and minority-group members. NASA's experience with this hiring effort was a very positive one; they were able to recruit graduates in the top of their classes, and very few of the candidates declined the Agency's job offer.

There is concern, however, about the large pay gap between NASA and private industry. At present, NASA administrators believe that because of NASA's unique mission, people will come to work for the Agency despite the pay gap.

Of greater concern is the increasingly poor image of the federal worker and the effect of this changing image on morale. These negative effects seem to be greater in laboratories outside the Washington area, such as Huntsville or Houston. BRAUNSTEIN believes that this image problem will have an impact on the future supply of engineers in the federal labs.

In summary, NASA does not face a shortage of engineers in its laboratories. Moreover, because of their recent successful experience in hiring new engineers, NASA does not see a shortage situation developing in the forseeable future.

James LING, assistant director for institutional relations, Office of Science and Technology Policy, spoke about the 1982 OSTP review of federal laboratories. This review panel, chaired by David Packard, looked at a representative group of federal laboratories within all the agencies. The study concluded that the Civil Service system, as it now exists, makes it very difficult for the labs to attract and retain top-quality scientists and engineers. One of the major problems is the significant pay gap between the Civil Service positions and private industry. As Table 1 illustrates, there are very large salary differentials between government-owned contractor-operated (GOCO) laboratories which typify private-sector establishments and those, such as the Naval Research Laboratory (NRL), that operate within the Civil Service.

Although people are attracted to the federal labs because of the nature of the work, there is a point after two to five years at which this pay differential will cause them to leave and take jobs elsewhere. If the federal employment situation cannot be made more attractive for technical people, the only alternative is to turn the federal labs over to contractor (GOCO) operation.

While the Packard Committee found that labs were able to hire adequate numbers of entry-level personnel, there appeared to be deficiencies in the quality of these new hires. The labs reported that at the salary levels they were able to offer, they could only hire graduates of the second- and third-tier schools in terms of quality or students in the lower grade-point average percentiles. In addition, the labs were unable to hire people from the outside at higher career levels because the lab salaries were not competitive; the rigid structure of the Civil Service system does not evaluate an experienced scientist or engineer on his technical abilities, only on his management experience.

LING concluded that the Packard study found the government-operated laboratories living on borrowed time. Top-management positions are being filled with people who have been in the system for many years. The rising stars are leaving in fairly alarming numbers, so that in perhaps five years the labs will have used up the reserve of research staff they have built in the last twenty years. Rebuilding this stock of researchers to carry on the program is where the laboratories' inability to hire experienced people from the outside becomes critical.

John LYONS, director, National Engineering Laboratory, National Bureau of Standards, reviewed recent NBS experience in hiring staff for their engineering laboratories. The NBS employs about 6,000 individuals, evenly split between scientists/engineers and support staff. Turnover

TABLE 1. Comparison of Laboratory Salary Structure, 1983

Lab	Director	Deputy Director	Associate Director	New Ph.D. (Top School)	New Ph.D. (Top 10%)	New Ph.D. (Superstar)
GOCO A	$110,000	$97,000	$86,000-90,000	$43,000	$45,000	$50,000
GOCO B	$110,000	$97,000	$86,000-90,000	*	*	*
GOCO C	$90,500	---	$84,000-88,000	*	*	*
NRL	$66,000	---	$66,000	$30,402	$30,402	$30,402

*Information Not Available.

SOURCE: Office of Science and Technology Policy.

is about 3 to 5 percent, a rate about as low as NASA's. LYONS began with two anecdotes that set the tone of his remarks. First, he told of Lewis Branscomb, a former director of NBS, who left his position to become Chief Scientist at IBM, roughly tripling his salary. LYONS also spoke of Ernest Ambler, current NBS Director, who as a presidential appointee is paid less than 50 of the Civil Service executives that he supervises and, yet, each year must distribute bonuses to these individuals.

LYONS noted that NBS lab scientists and engineers hold advanced degrees and primarily do bench research. Although the engineering schools currently have very high enrollments at the baccalaureate level, this is not the case for master's or doctoral candidates, which is the hiring pool for NBS. As a result, NBS, which is traditionally physics-oriented, often hires physicists and trains them as engineers for their center for Electronics and Electrical Engineering. Physicists account for about one-half of the professional staff in that center.

LYONS went on to review the supply situation in each of the engineering centers. The chemical engineering center is now benefitting from the favorable hiring market caused by the shutdown of the oil shale business. Prior to that business downturn, NBS could not hire Ph.D. chemical engineers because of the pay gap with the private sector. Even now, LYONS noted a $15,000 salary differential, but because of the current oversupply, chemical engineers can still be hired. Roughly the same situation exists in civil engineering, where NBS can hire because of the weak job market. Civil Service salaries do become competitive with academe at mid-career levels, such as GS 13-14. However, NBS is not competitive at the senior level; they simply cannot recruit for top research engineers or managers.

In manufacturing engineering, they have been able to fill entry-level positions despite the low salaries because of their unique automation research facility. Engineers will come to work at this facility regardless of the pay gap. They expect, in fact, that people will leave the automation lab in a few years. NBS considers this turnover to be a technology-transfer contribution. Again, they are unable to hire at the senior levels in manufacturing engineering.

At the entry-level, NBS salaries for electronics engineers are not competitive, but they do become comparable at the GS 13-14 level. NBS expects to hire individuals with five to seven years' experience, people who choose to leave industry to do bench research and be able to publish. In some areas, such as microwave engineering, people are extremely scarce. Ph.D. electronics engineers, mathematicians, and computer scientists are extremely hard to find, so NBS hires at lower degree levels in those disciplines.

LYONS is concerned with two potential changes in the Civil Service system. First is the budget proposal to reduce the number of GS 11-15's. While these may be managers in most federal agencies, these are the bench researchers at NBS, so reduction in these individuals would seriously impair research productivity. The other issue is an OPM proposal to withhold raises for certain engineers who have higher salaries because they were thought to be in a scarce discipline, which OPM has now decided is no longer a shortage area.

For the future, the supply and demand situation in fields such as petroleum, chemical, and civil engineering will be highly dependent on how many universities begin to turn out graduates in that area. At this point, manufacturing engineering is not thought of as a true discipline, and very few universities have programs in manufacturing.

NBS is likely to follow a strategy of using unconventional methods for hiring engineers. Their experience has been that if they can get students into the labs for the summer, or in a co-op program, then the likelihood of hiring them as permanent employees is greatly increased. LYONS felt that the Bureau would need more authority to conduct such programs in the future.

Another category of successful recruitment strategies is the NRC's research associateships program. The Bureau of Standards has about 25 people in the program, which lasts two years. Conversion of these people to full-time employment is better than average, but less so for engineers than for scientists.

LYONS concluded by commenting that often the system itself is one of their worst enemies. As long as six months can elapse between decision to hire an applicant and the making of a formal job offer. The best people do not wait around for six months, so they are lost to NBS time after time. LYONS concurred with Braunstein's assessment of the NASA situation by noting that NBS employees are feeling the impact of the low esteem associated with working for the government.

Finally, LYONS expressed concern about the declining proportion of U.S. citizens earning engineering doctoral degrees, particularly in light of NBS's not being able to hire non-U.S. citizens because of the nature of the work.

Norman SELTZER from the Office of Energy Research, Department of Energy, opened his remarks with a description of the DOE's data-collection and analysis program on scientists and engineers involved in energy-related activities. Over the years, DOE has developed a comprehensive data base on scientists and engineers, piggybacking questions on energy-related activities on NSF, NRC, and Census manpower surveys. They have also contracted with the research staff of the Oak Ridge Associated Universities to help analyze these data. Surprisingly, there does not yet exist a detailed data base on scientific and engineering personnel working at GOCO's, a very sizable segment of the energy-related work force.

SELTZER went on to discuss the impact of changes in the federal budget as well as changes in industrial activity on the utilization and need for scientists and engineers. SELTZER spoke primarily about the large multiprogram labs such as Argonne and Livermore. Funding for energy R&D at these labs decreased between 1981 and 1983; but was expected to increase somewhat in the next year. During the second half of 1983, these labs employed about 6,000 engineers out of a total 11,000 engineers in all energy R&D facilities. The percentage of advanced-degree engineers at these labs is rather high, with a great many of them being Ph.D.s.

The turn-around in 1983-1984 funding is expected to provide an increased demand for Ph.D. engineers in all fields except for electrical engineering. The largest estimated increase in demand for graduate-level engineers is in the nuclear/mechanical area. Overall, total engineering employment is expected to increase in 1984 and, if defense-related funding remains high, continue to increase in 1985 and 1986.

The personnel managers in these labs do not indicate any concerns about recruiting the people they will need. They feel that because of the salaries and fringe benefits they can offer, they are very competitive with private industry in hiring top-level engineers and scientists from prestigious schools. Unless there is some undue stress on the system, such as vigorous resurgence in the economy coupled with increases in expenditures in specialty areas by industry as well as government, they do not report any broad-range concern.

Over the next five years, the outlook seems to be for moderate growth but probably at a slower rate than has occurred in the recent past. The only potential indication of a labor shortage is at the Ph.D. level, where graduates in engineering, physical, and life sciences have lagged relative to growth at the bachelor's level.

SELTZER expects that there will be somewhat lower demand at the B.S. and M.S. level over the next several years. One of the causes of this downturn is the shift of federal R&D money toward basic and applied research and away from demonstration and commercialization activities. Accordingly, the supply at the bachelor's and master's levels should be adequate in the energy area.

At the Ph.D. level, there may be trouble hiring sufficient numbers of people in areas such as petroleum engineering, materials science, and perhaps nuclear engineering. If the very significant numbers of foreign nationals earning engineering Ph.D.s are counted in the supply figures, then the concern about shortage lessens considerably, and it may only be in petroleum engineering where shortages might occur. **SELTZER** emphasized the need to study more carefully the role of foreign nationals earning degrees in the U.S. and the proportions remaining here for employment.

Herbert **RABIN**, former deputy assistant secretary of the Navy and now at the University of Maryland, provided the DoD laboratory perspective on the engineer supply/demand issue. In 1982, Dr. **RABIN** was involved in a study of the status of scientists and engineers in the 71 defense laboratories. The DoD labs have a total work force of 60,000, including about 23,000 scientists and engineers, and an annual budget of roughly $6 billion. There is wide variation among DoD labs in size, mission, composition of the work force and relationship to the military services. DoD laboratories tend to be engineering-oriented; engineers account for 68 percent of the science/engineering work force.

Over the 1977-1981 period, the number of scientists and engineers in the labs has remained fairly constant as has the distribution by level of education--bachelor's, master's, or doctorate. One-half of the scientists and engineers in DoD labs are at the GS 13-15 grade levels.

The study found concern on the part of lab directors about losses of experienced people. Lab directors reported that significant numbers of GS 13-15 researchers are being drawn to higher-paying jobs outside the labs. Even at the highest salary levels permissible within the Civil Service system, there is a substantial pay differential between the DoD labs and the private sector over all GS levels. The gap becomes widest at the executive, GS 15, level.

At the same time, however, the average turnover rate over the whole DoD system was 6.4 percent. Attitudes in the labs appear to be similar to those at NASA and NBS. The average vacancy rate was 5 percent, although there were some variations in this figure, with a number of labs having vacancy rates from 10 to 20 percent for scientists and engineers.

Two approaches were taken in the study to gauge the quality of the laboratory work force. First, lab directors were asked to provide their perceptions of changes in quality of the work force over time. About 80 percent of the directors said that the overall quality of the work force was "good to excellent;" the remainder reported "average to very good". As for currency of the lab employees, 60 percent reported "very high," but 40 percent indicated that there were problems. Similarly, quality of new hires was seen as mixed, with some saying "good to adequate," and others reporting problems.

Second, the rank in graduating class of scientists and engineers hired by the labs in 1981 was studied. The scientists hired were found to be in the first quarter to top half of their classes, with engineers predominantly being in the top half of their classes but slightly lower than the scientists.

This study, too, found morale problems among scientists and engineers in the labs, mostly centered around frustrations in working with the rigidity of the bureaucracy. The resulting negative image of work in the labs was found to be a strong factor relating to the general health of the laboratories.

Discussion

Following James LING's presentation, discussion focused on the problem of hiring and retention of the "rising stars"--those individuals who are the leading researchers at the federal laboratories. David BRAUNSTEIN noted that at NASA, turnover has been particularly high at the associate administrator level. These are among the most able people at NASA, and their average stay in those positions is less than 1-1/2 years. It is very difficult to establish stability at that level of the agency with such high turnover.

James LING outlined some of the problems with hiring at senior agency levels. First, the salary for individuals at Executive Level 5 is lower than that of career Civil Service grades, so that people hired into these positions find that some of the senior people working for them earn higher salaries. In addition, presidential appointees don't receive moving expenses. Moreover, to be confirmed, an individual must go through the Presidential Personnel System, which includes hearings before Congress and the exposure of all of one's personal finances, which can be considered an invasion of privacy. Given those burdens, it is perhaps not surprising that people do not always enter these positions for the best reasons--they may be in the process of a career change, or they are looking for something to do after their retirement, or other reasons peripheral to bringing the best technical talent to the federal government.

LING explained that there is an experiment under way at the Naval Ocean Systems Laboratory in San Diego to allow more flexibility in pay for scientists and engineers. The ten Civil Service grades which typically cover technical people have been aggregated into four. Thus, if there is a certain type of engineer that is in short supply, the lab has the option of hiring a person in the broad category (for example, Grade 13, 14, and 15 at the top level of 15 rather than as a 13). While this kind of flexibility is helpful, the only way to solve the problem at the upper end of the pay scale is to somehow get waivers to exceed the pay cap.

In response to a question concerning what approaches OSTP is taking to deal with these problems, LING said that several proposals were under consideration, including expanding the San Diego experiment to other federal facilities. However, it is difficult to determine who should be covered under such a pay system, should you cover all scientists and engineers in the Civil Service, or only those in the federal labs, or just those in selected federal labs? An interagency group is now working on the problem of attracting and retaining technical people in the federal government.

Of course, these kinds of proposals will not be adopted across the board by the Administration. For example, the OSTP goal of ensuring the vitality of the country's science and engineering base may impact on the budget through higher salaries, which OMB is likely to resist because of their goal of controlling the deficit. Each part of the Administration has its role to play in reaching a solution.

LING pointed out that just a few key people can drive a whole laboratory. One of the Packard panel's key concerns was that without these superstars--those in the top 10 percent of their graduating classes--the whole lab system could sink into mediocrity. Consequently, it's not a matter of giving everybody more pay; it's a matter of being able to get key people in a competitive market.

John LYONS voiced agreement to LING's statement that the labs could be living on "borrowed time." LYONS explained that the feeling at NBS was that they were on the ragged edge, that the possibility of losing a substantial portion of their best people seems very real. LYONS felt that the GOCO concept of moving labs out from under the Civil Service was a possible solution to the salary problem. GOCO status would not be applicable to NBS, however, because the role of the Bureau of Standards as a provider of impartial service, independent of the private sector.

LYONS pointed out that one gratifying aspect of work at the NBS is the number of people who stay on past normal retirement age to continue their research. These individuals love to work at the Bureau of Standards and stay on, even though their retirement incomes would be comparable to their current earnings.

Discussion following Harold RABIN's presentation centered on the issue of retention of technical personnel in the DoD labs. One question concerned the finding that although DoD labs were able to hire personnel at entry-levels in state-of-the-art fields, there appeared to be mobility out of the labs after a few years. Did the lab system consider itself to be a training ground in technology for private industry? RABIN agreed that this was the case, but pointed out that in fact, this was a traditional role throughout the military services. Nevertheless, this training-ground loss is not substantial when viewed across all DoD labs. For example, roughly 40 percent of new GS 12's were hired from the outside, with 60 percent coming from internal promotions. Turnover at that level is about 5 percent. At the GS 13 level, only about 5 percent are from outside; most come from inside the labs. Of course, these are the levels where the Civil Service salaries are most competitive with the private sector.

Robert STAMBAUGH asked whether there was any evidence that the relationship between scientists and government was different in other countries; are their best scientists and engineers in the government?

David BRAUNSTEIN responded that in Japan, it is an honor to work for the government. The top people are recruited directly from university graduates; there is no equivalent to our Civil Service. LING stressed that the Japanese attitude toward working for the government as a prestige job shows the importance of morale.

LYONS noted that in contrast to Japan, government workers in England have experienced a system similar to that in the U.S., but for a longer time. The result has been work stoppages and professional strikes.

LING maintained that the problems with the Civil Service were fundamental issues, and would need to be addressed at high levels of the government.

When asked about the Senior Executive Service (SES), James LING reported that most of its effects have been negative. BRAUNSTEIN agreed that at the outset, the SES was an initiative with great potential, but many promises made at the beginning have not been fulfilled. Many of the benefits advertised have eroded; for example, bonuses are limited to 20 percent. In addition, LING pointed out that the bonus pay is capped, so even though you are awarded a $10,000 bonus, you may only receive $4,000 because of the pay cap.

PLENARY SESSION

Daniel DRUCKER opened the afternoon session with a question concerning the composition of the group of experienced people who move into engineering positions from other fields. In his experience in civil and mechanical engineering, these individuals are not physicists who cannot find work, but rather people from the shop floor who have worked their way up. The IBM perception seems to be that they are much higher-level people who are making lateral moves into engineering.

Jerrier HADDAD, Chairman of the Academy's Committee on the Education and Utilization of the Engineer, responded that in companies like IBM, roughly 20 to 30 percent of the people doing engineering R&D are mathematics and physical science graduates. While over the past twenty years the number of technicians upgrading themselves to the point of doing professional engineering work has steadily declined, there has been a tremendous surge in recent years in upgrading due to the changing nature of engineering jobs. For example, fifteen years ago, microcoding for computer applications was done by an engineer; today the same work is performed by programmers with liberal arts B.A.s or high school backgrounds. A similar case exists with CAD systems, which 4-year technology graduates are using to do bona fide engineering work. Thus, the combination of upgrading and the changing nature of engineering practice has resulted in roughly 30 percent of the individuals holding engineering jobs having non-engineering degrees.

Robert STAMBAUGH continued the discussion of the makeup of this "second" group by asking about the job performance of these non-engineers: our assumption is that they are not doing a very good job, but we have heard today that perhaps they are not doing too badly. What needs to be done is data collection and research on what kind of people are in the "second half," and we might find that their performance is better than we expected. If, on the other hand, there is a problem with this second group, we need to be more aggressive about doing something about it.

Charles FALK, of the National Science Foundation noted that the results of NSF's Post-Censal Survey should provide some broad insight on mobility within and out of engineering. Two questions seem to be central to this issue: first, what is the composition of that mobile group? and second, to what extent are employers satisfied with their performance as compared to that of individuals specifically trained in that field? Information relevant to the first question is now available and can be analyzed, but answers to the second question will be much more difficult to obtain. For example, what kind of source would one go to in a company to answer such a question? Would it be the vice president for production? the director of personnel?

Dr. STAMBAUGH agreed that the essential problem is to obtain information on performance rather than by label as is currently collected.

Dr. HADDAD presented examples of the wide variety of non-engineering personnel who are highly useful to industry. First are bachelor of technology graduates or technicians, who have ideal backgrounds for working with CAD systems whereas a degreed engineer tends to become impatient with the repetitiveness and detail involved. Second are the M.S.- or Ph.D.-holders in mathematics, chemistry, or physics who are very, very happy in engineering jobs and whose companies are quite satisified with them. One needs to examine both ends of that spectrum when looking at this non-engineering group.

Daniel HECKER of the Bureau of Labor Statistics noted that some of the apparent movement into and out of engineering may be an artifact of our data-collection methods. If we used a longer time span, for example, an individual who leaves an engineering position to work on a short-term management project and then returns to his or her former job would remain an engineer rather than be counted as a person moving from an engineering to a management occupation.

Harold WOOL, an independent consultant, mentioned two possibilities for measuring the performance of the non-engineer group. First is the market test of salary as a measure of performance, which can be flawed because the lack of a credential may be a critical factor in keeping workers' earnings down. A second possibility would be to develop a detailed list of the kinds of functions performed by engineers and then to find out about the kinds of people and their backgrounds being used for these functions. This method should yield a measure of where elasticity exists in the utilization of engineers.

Charlotte KUH of AT&T spoke of the changing demography of the engineering system. Industry is now able to provide entry-level positions for many people, including engineers. If these individuals follow the normal lifecycle for engineers--starting out with close supervision, becoming more autonomous, and eventually moving into management--it is unlikely that there will be enough middle-management positions in the next ten years relative to the supply. The adjustment problem in the next five to ten years will probably not be at the entry level but will be with these relatively experienced engineers who are not moving into management-level positions.

Robert WEATHERALL, director of career services at MIT, emphasized that the day's discussions reflected that we have not concentrated nearly enough on the quality of the engineering labor force. For instance, Japanese firms are so concerned about quality that they had students at MIT take a quiz last year before interviewing them. We will not have gotten very far if we continue to work with quantitative statistics without trying to find some measure, or measures, of quality.

CONCLUDING REMARKS

Michael McPherson, Moderator

The following remarks can hardly pretend to summarize the product of an unusually rich day's discussions. They are rather in the nature of thoughts provoked by listening through the symposium's presentations and discussions. These thoughts cluster around several key notions: quality, mobility, and the timing and location of training. I should underline that the following observations are very much my own views; they are not necessarily the views of OSEP or the NRC. They are certainly not views shared by all panel participants.

I must begin by agreeing with Michael Mandel about the rather large measure of agreement among the studies that we examined at the symposium. I disagree mildly with him about the American Electronics Association study, which I think actually seems to imply rather larger demands than the other three studies do. But his broader conclusion is very much on the mark; the studies by the Business-Higher Education Forum, the Bureau of Labor Statistics (BLS), and the National Science Foundation (NSF) all exhibit striking agreement on the demand we can expect for engineers, not only in the aggregate but also by fields of engineering. Such agreement is, as Mandel said, somewhat reassuring. I would find it still more reassuring if I did not also notice that all three of those studies basically used the same model to predict demands. That's quite explicit, of course, with the Business-Higher Education Forum work, which simply adopted the BLS's estimates. The DRI (Data Resources, Inc.) model that NSF used is run largely on the same principles as the BLS model. One would feel even more confident if the studies under review arrived at agreement on the basis of radically different methods for deriving the results; but at least we can have some assurance that the people did the numbers right, since they came out the same in all three cases. More importantly, because the common methodology of these studies makes a good deal of sense, we have some reason for confidence in them. On the other hand, the American Electronics Association study, which is something of an outlier, does have some important methodological weaknesses that were identified in the discussion and commentary at the symposium. There is, I think, therefore good reason to discount those results.

On the supply side there is also a large measure of agreement. In that case, the consensus is that we have very limited knowledge about the supply of engineers. The NSF people have, conceptually, the most illuminating approach and the one with the most promise for solid future results; but their staff are frank to acknowledge that the empirical quality of what they have so far been able to do on the supply side is not terribly good and that a lot more work needs to be done. We don't have a sufficiently good understanding even of the "new entrants" part of the picture, of how undergraduates make their decisions about whether to go to college or what to major in. The National Center on Education Statistics' projections that NSF relies on are really very mechanical and don't have any behavioral decision-making in them and, therefore, are not too reliable. But our understanding of that part of the supply of engineers who are "in-mobile" from other fields is even less adequate. As several participants noted, we don't even have clear information about where people are coming from, where they are going, and in what ways mobile people are different from in-mobile ones. We certainly have even less in the way of a good economic and social understanding of what underlies those movements and how to explain and predict them. A lot of important work remains to be done there. The agreement on the supply side, then, is that this work needs to be done.

Both the presentations and discussions thus point to the conclusion that we are confronted not so much with disagreement, but rather with agreement on some very important limitations on what we know. I think that's real progress. This was, as these things go, a rather well focused symposium, and I think substantial concensus emerged on what we need to know more about.

Now the question is "Where does all that agreement lead us in terms of how we should interpret it and where we should go next?" One place it leads us is to Jerry Haddad's Study on the Education and Utilization of Engineers (National Academy of Sciences, Commission on Engineering and Technical Systems), which is obviously going to look for deeper answers and for more progress on these questions. I hope the symposium's efforts give that group some more fuel and more to think about in pursuing those efforts.

As we look toward the analytical and policy implications of the symposium's discussion, several major points emerge. One that Harold Wool stressed, and that other discussants pointed to as well, is that one has to become more sophisticated about what "shortage" means. "Shortages" in the real world don't usually imply huge numbers of unfilled jobs. Labor markets adjust in one way or another; they compromise when the fit isn't what it should be, and they compromise in a variety of ways. A key empirical issue which we don't know nearly enough about is how that compromise process works. The compromise comes partly through people's switching from one field to another in response to excess demands in some fields and excess supplies in others and partly from the upgrading of personnel who don't have the technical credentials for the job that they are doing. It may also come partly through wage increases, which may attract people to the field at the same time they reduce the number of jobs being offered. Or, compromise may come from increasing the productivity of people who are working in those jobs, and so on. Sorting out the roles and relations of all these adjustment processes is a very complicated question on which the NSF in its recent work is making a good start. Our empirical understanding of these processes has to be improved substantially before we can gain a real grasp on how labor markets, including the engineering labor market, work.

Beyond the empirical issue, we also face the policy, or the evaluative, issue of how we should think about these shortages. There we have at least two questions, knowing that labor markets compromise and adjust: (1) "How well do they adjust?" and (2) "What kind of costs must be borne, and who bears them, when these adjustments have to take place?" I am merely seconding remarks from a number of the participants today in saying that at this point understanding the quality implications of mobility becomes a really critical question. In the late 1950s and the 1960s, we had a huge expansion in the demand for engineers and other kinds of scientists because of the space program. Many compromises were made, and many apparently worked out very well; but also, a lot of costs were borne in doing that--by firms investing in training or making do with personnel who were less than ideally qualified, by workers relocating and retooling, and in other ways. It strikes me that one thing we ought to pursue besides more econometrics is more history: "How did that all really happen?" and "What unexpected costs and, for that matter, unexpected benefits came from those switches?" The unexpected benefits really do deserve attention: field switching is surely one way of getting new insights and surprising, new combinations of perspectives on a problem.

A different kind of question is "To the degree we recognize that the markets are working imperfectly and that there are costs to these adjustments, can we really anticipate well enough to do anything about avoiding those costs?" Pat Hill Hubbard said at one point that people are very rigid, and therefore, if the supply-demand balance is imperfect, forced adjustments will inflict very large costs. But it's not clear that that's an acceptable answer. If the reality is that we lack the skill and the institutional flexibility to fine-tune so that everybody is matched to the job he or she was trained for, we may need to learn to be flexible in other ways. We shouldn't accept personal or institutional rigidities as absolute givens without a careful look.

Thus the <u>quality</u> and the <u>mobility</u> questions are closely intertwined. We need to know how much and what kinds of mobility there are. We need to know how various kinds of job switches affecting various categories of personnel (classified by age, experience, degree level, and so on) affect productivity. This will require us to think seriously about the kinds of questions Harold Wool pressed in discussion: How can we conceptualize and get some crude operational measures of quality? I sensed wide agreement today that quality of the work force cannot simply stay in these discussions as the residual category that we all admit is important but that we don't do anything about; it has to be thought about hard. There is a similar need to focus closely on questions about quality of education: trying to disentangle value added by schooling from the intrinsic quality of the students, investigating seriously the relation between value-added and faculty work load, and so on. Bob Armstrong from DuPont reported a subjective judgment that the quality of graduates DuPont sees is terrific, but Harry Shull (University of Colorado, Boulder) pointed out that DuPont is seeing the best people. Such subjective judgments are important in any study of quality, but we need to think about how to pull them together with other data in a systematic way. As Bob Weatherall observed, we don't seem hesitant to use crude numbers to measure quantitative aspects of engineering education; it would be worth experimenting with crude numbers related to quality as well. But as much as we need better numbers and better models, I suspect we may need a better grip on the conceptual issues even more.

That leads me finally to several remarks about the question of training and retraining. We have to expect to continue to be dealing with an economy where the requirements placed on our technical people change at a dramatic rate. Inescapably, the particular training and knowledge technical workers possess become obsolete quickly, and yet we must keep supplying an appropriately trained set of people to meet society's needs. It is clearly not an adequate solution to say that every time there is an innovation, the only source of people to deal with the innovation must be brand new people coming out of college. A tremendous waste of resources results when earlier generations of able people are "thrown on the junk heap," as Ronald Kutscher put it earlier today. Moreover, as Charlotte Kuh noted, the option of remaking technical people into managers to make room for new technicians is becoming less viable, as prospective demographic movements reduce the number of managerial openings. We really have to think hard about where training should take place--on the job, in colleges, or perhaps in hybrid environments--and who should bear the responsibility for retraining of people--both the retraining of engineers who can be recycled back into new technologies and the training of people who may have a degree in physics or another science to get what they need to become engineers.

I sensed in some of the remarks today a feeling that a new bachelor engineer is somehow free--well equipped and ready to go--whereas a person who was doing something else will either involve retraining expense or will perform less capably in the job, or both. Now, conceivably the fresh bachelor's engineer may appear "free" to the employer--although with starting wages for engineers rising faster than experienced wages, that's not so clear--but he or she is certainly not free to society. From a social point of view, the question to focus on is this: If you have a specific employment need two years down the line, do you want to take a college sophomore and train that man or woman for two years to do the job, or do you want to take somebody who has already gotten a lot of training and train that person for two years to do the job? When you look at it that way, the essential symmetry between training and retraining becomes clear.

Finally, questions arise about the content of engineering education. If we can anticipate that most technical workers will need substantial retooling several times during their career, it makes sense to wonder whether engineering education can do more than it now does to prepare them for such future flexibility. That's a hard pedagogic judgment to make and not one that an economist should claim to make for engineers. Obviously, people do need highly-specialized, technical skills, but can we think about ways to educate people to make them more flexible than they are now? Can we think also about ways to run organizations that won't, after five years, have people in a rut that leads us to say that there's just nothing else they can do but continue to do what they are doing? This strikes me as partly a question of mores and guilds, of people being looked on with suspicion if they don't have the right paper credentials, and partly a question of the intellectual content of what is being taught. Perhaps we need to think more about really sound, basic scientific education in college with industry adding more of the specialized skills. Last but not least, flexibility is very importantly a question of psychology. People do get into ruts, and if we want a highly flexible work force, and I think that we do, we have to find ways to encourage people from time to time to climb out of their ruts and look around.

APPENDIX A: AGENDA

SYMPOSIUM ON LABOR-MARKET CONDITIONS FOR ENGINEERS

Lecture Room
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C.

February 2, 1984

9:00 Welcome
Robert M. White, President, National Academy of Engineering

9:10 Introduction
Alan Fechter, Executive Director, Office of Scientific and Engineering Personnel

9:20 Organization of the Program
Michael McPherson, Department of Economics, Williams College

9:30 Supply/Demand Models I: Following each presentation, questions will be entertained from the floor.

<u>Presenters</u>

Pat Hill Hubbard, Vice President for Engineering Education, American Electronics Association: <u>Technical Employment Projections 1983-1987</u>

William R. Upthegrove, Regents Professor of Engineering, University of Oklahoma: <u>Engineering Manpower and Education: A Precis and Commentary</u>

Ronald Kutscher, Associate Commissioner, Bureau of Labor Statistics: <u>Future Labor Market Conditions for Engineers</u>

10:30 Break

10:45 Supply/Demand Models II: Following each presentation, questions will be entertained from the floor.

<u>Presenters</u>

Jean Vanski, Program Analyst, Division of Science Resources Studies, National Science Foundation: <u>Projected Labor-Market Balance in Engineering and Computer Speciality Occupations, 1982-1987</u>

11:45 Supply/Demand Models: Discussion

Discussants

W. Lee Hansen, Department of Economics, University of Wisconsin-Madison

Michael Mandel, Department of Economics, Harvard University

Harold Wool, consultant

12:45 Discussion from the Floor

1:00 Luncheon Buffet

2:00 Concurrent Sessions: Case Studies on Labor-Market Imbalances

Panel A: Faculty Shortages in Engineering Departments

Chair: Daniel C. Drucker, Dean, College of Engineering, University of Illinois-Urbana

Panel: Samuel Hulbert, President, Rose-Hullman Institute of Technology

Fred Landis, Professor of Mechanical Egineering, University of Wisconsin-Milwaukee

W. Edward Lear, Executive Director, American Society for Engineering Education

David R. Reyes-Guerra, Executive Director, Accreditation Board for Engineering and Technology

Panel B: Engineering Employment at Federal Research Laboratories

Chair: Herbert Rabin, Director, Engineering Research Center, University of Maryland-College Park, and Associate Dean, Department of Engineering

Panel: David Braunstein, Executive Director for Special Projects, National Aeronautics and Space Administration

James G. Ling, Assistant Director for Institutional Relations, Office of Science and Technology Policy

John Lyons, Director, National Engineering Laboratory, National Bureau of Standards

Norman Seltzer, Chief, Manpower Assessment Branch, U.S. Department of Energy

3:45 Summary of Concurrent Sessions by Panel Chairpersons

4:15 Discussion from the Floor

4:45 Symposium Summary
Michael McPherson, Department of Economics, Williams College

5:00 Closing Remarks
Alan Fechter, Executive Director, Office of Scientific and Engineering Personnel

5:30 Reception

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