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ABSTRACT

This report summarizes the deliberations of the Office of Scientific and Engineering Personnel's Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers. The purpose of this report is to help the profession make existing data bases on engineers more complete, accurate, and compatible. The report is also intended to help funding agencies with their data collection and analytic efforts in the 1990s. The current data bases were evaluated in terms of occupational mobility and flow dynamics, technical currency, international flows of engineers, and the role of underrepresented groups in engineering. Two major conclusions were reached: (1) current data bases are quite valuable in understanding engineering labor markets; and (2) the value of data bases can be increased significantly by improved cross-correlation, dissemination of unpublished materials, and the increase of their longitudinal nature. Fifteen recommendations are included. Four appendices are included. The first is a background paper by Engin Inel Holstrom which includes an overview of engineering databases, specific data on databases produced by 10 organizations, and outlines of engineering taxonomies. The remaining three appendixes provide the agenda, a list of 60 participants, and an 11-page summary of discussions of a Workshop on Data Needs for the 1990s, held March 28, 1988. (ML)

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Engineering Personnel Data Needs for the 1990s

Occupational Mobility and Flow Dynamics
Maintaining Technical Currency
International Flows
Underrepresented Groups: Women and Minorities

SE

Engineering Personnel Data Needs for the 1990s

Committee on Data Needs for Monitoring
Labor-Market Conditions for Engineers
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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FOREWORD

The topic "Data Needs in the 1990s for Monitoring Labor-Market Conditions for Engineers" is most important as the United States faces the problems generated by a global economy, a strongly internationalized engineering enterprise, and industrial competitiveness. To grapple with the policy issues that relate to the character of the U.S. R&D enterprise, our industrial capabilities, labor-market conditions for engineers, and the education of engineers, improved data are needed. Policies need to be based on quantitative, not anecdotal, data. The National Science Foundation for many years has been in the forefront of producing quantitative information on the basis of which policy decisions can be made--particularly in its *Science and Engineering Indicators*, which presents quantitative information that has been invaluable in shaping educational, governmental, and research policies.

At the workshop convened on March 28, 1988, participants considered data needs for the next decade. The kinds of data that we will need will depend on what we consider important information required for policy and management decisions. The four major issues addressed at the workshop--occupational mobility and flow dynamics, international flows of engineers, technical currency, and the role of underrepresented groups in engineering--generate requirements for data not now available.

Consider, for example, occupational mobility: several years ago the impact of the military buildup in this country upon the availability of engineers for civil industry was an issue. The National Research Council's Office of Scientific and Engineering Personnel (OSEP) examined quantitative data that revealed that during past buildups, there was a remarkable amount of occupational mobility/fungibility. The problem was found to be less serious than anticipated. In the future, as the military buildup levels off, the reverse may be of concern. The question of occupational mobility is central.

Technical currency is another issue that has been discussed widely. In a rapidly changing technological world, technical obsolescence is a continuing problem. Although many large corporations have excellent career-long education programs and professional engineering societies are deeply involved in continuing education activities, as are U.S. universities, there is no national policy that addresses this issue. It is important to have data to determine whether governmental intervention is desirable or whether the engineering community as a whole needs to take action.

There are growing concerns in some parts of the engineering community about the effect of international flows of engineers, especially from foreign countries to this country, on the U.S. engineering enterprise. How we address these concerns in the United States will be important. OSEP, in a recent study, found serious needs for data on which one could base policy decisions with respect to international flows.

The problems of women and minorities in engineering have been with us for a long time. There has been a significant increase in the number of women entering engineering, but the same is not true of minorities. It seems strange to have forecasts of a shortage of engineers which can only be met by foreign inflows of engineers when the United States has an underutilized talent pool in its women and minorities. Why are they not moving in adequate numbers into the engineering professions, which represent some of the most exciting, best-paying jobs in the country? Better quantitative data are needed to answer that question and to formulate policies.

Clearly, we need decidedly better and more relevant quantitative data if we are to monitor with confidence the dynamics of the engineering component of the nation's technology base and formulate wise national engineering manpower policies. This report provides guidance to the National Science Foundation and other agencies for the collection of data to serve the needs of the country.

Robert M. White
President
National Academy of Engineering

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PREFACE AND ACKNOWLEDGMENTS

A major concern of the National Science Foundation (NSF) is gaining a better understanding of the large and diverse number of data bases focused on the engineering community. An earlier study conducted by the National Research Council's Committee on the Education and Utilization of the Engineer (CEUE) and partially funded by NSF had recommended that (1) the data-collection agencies use common definitions to identify and collect consistent information on different segments of the engineering community and (2) data-collection agencies be convened to discuss how best to make those data more complete, accurate, and compatible. Responding to CEUE's recommendation, NSF asked the National Research Council to conduct a study of data needs for monitoring engineering labor-market conditions that would address the definitional and methodological differences of existing data bases, mechanisms to reduce current information gaps, and future data needs. In particular, as NSF embarked on an ambitious effort to evaluate and redesign its Scientific and Technical Personnel Data System for the 1990s, it was interested in answering five questions:

1. Among the major data bases, what are the similarities and differences in the definition of "engineer" and "the engineering community"?

2. What are the strengths and weaknesses of each of the data bases, and what does each try to measure?

3. How might the data bases be used in conjunction with each other? Should they be integrated into one large data base?

4. What types of issues cannot be addressed by using the current data bases?

5. What sources of international data on engineers are available, and what types of comparisons are feasible?

The introductory chapter of this report summarizes the activities undertaken by the study committee in the course of answering these questions. The Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers identified the major sources of information on engineers in the U.S. work force and considered the various definitions of "engineer" used within them. Chapter 2 briefly cites the definitions used by the Bureau of Labor Statistics, National Science Foundation, and the Research Council's Committee on the Education and Utilization of the Engineer. Appendix A describes these data bases, as well as their strengths and weaknesses. Next, the committee looked to the future rather than to the past to articulate issues most linked to the formulation of federal policy in a rapidly changing environment. The committee discussed various current trends that have implications for the utilization of engineers in the next decade and identified four major policy issue areas that are expected to increase in prominence: occupational mobility and flow dynamics, international flows, maintaining technical currency, and the role of underrepresented groups in engineering. As shown in Chapter 3, "Data Bases and Policy Issues," many of the information needs of researchers and policymakers can be served by the current data bases on the engineering work force; however, data gaps do exist in some areas. Thus, in Chapter 4, the committee presents conclusions and recommendations for actions that will make the data bases more valuable in their content, approach, and diversity.

The Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers appreciates the special assistance that it received from a number of individuals. Erich Bloch, director of the National Science Foundation (NSF), initiated this study as a result of the CEUE recommendations. Richard J. Green, assistant director of NSF's Directorate for Scientific, Technological, and International Affairs (STIA); Carl W. Hall, acting assistant director of NSF's Directorate for Engineering; and Mary F. Poats, special assistant in the Directorate for Engineering, contributed to the development of this project. Staff within STIA's Division of Science Resources Studies worked directly with staff at the National Research Council to structure this project: William L. Stewart, division director; Charles H. Dickens, head of the Surveys and Analysis Section; and Michael F. Crowley, director of the Scientific and Technical Personnel Characteristics Study Group (STPCSG). Particular appreciation is extended to Melissa J. Lane, STPCSG economist, who served as the NSF staff officer on this project.

At the Research Council, the study committee is grateful for the support provided by staff in the National Academy of Engineering (NAE)--particularly Robert M. White, president; Alexander H. Flax, home secretary; Jesse Ausubel, director of the program office; and Hugh H. Miller, who served as liaison between the committee and the NAE--and in the National Research Council's Office of Scientific and Engineering Personnel (OSEP). Alan Fechter, OSEP's executive director, supported the project from its developmental stages in 1986 and provided helpful counsel during the committee's intensive 6-month study of the issue, "What data needs exist for one to monitor the engineering labor market in a comprehensive manner during the 1990s?" Linda S. Dix, staff officer, organized the various committee activities, including the workshop convened on March 28, 1988, conferred with staff at the numerous data-collection agencies and professional engineering societies to ensure that descriptive information about each data base was correct, and had administrative responsibilities for this study. Engin I. Holmstrom, consultant to the study, wrote the background paper and drafted this report. Finally, Constance F. Citro, study director for the Panel on Decennial Census Methodology and for the Panel on NSF Scientific and Technical Personnel Data Systems in the Research Council's Commission on Behavioral and Social Sciences and Education, offered many insights as the project was developing.

Much information presented in this report was gathered during the committee-sponsored workshop. The committee greatly appreciates the guidance provided during the small-group discussions by four researchers recognized for their particular expertise: Pamela Atkinson, former NAE fellow now at the University of California-Berkeley, who led the discussion on flow dynamics and occupational mobility; Michael G. Finn, with Oak Ridge Associated Universities at the time of the workshop and now director of studies and surveys in OSEP, whose knowledge of international flows of engineers enhanced that section within the report; William K. LeBold, director of engineering education research studies and information systems at Purdue University, whose knowledge of the importance of and methods for achieving technical currency in engineering contributed much to the discussion; and Betty M. Vetter, executive director of the Commission on Professionals in

Science and Technology, who has a wealth of knowledge not only about women and minorities in engineering but about many of the other topics discussed during the workshop.

In addition, the committee thanks those who attended the workshop and contributed to its deliberations. Approximately 60 individuals represented the federal data-collection agencies, professional engineering societies, industrial and university employers of engineers, and researchers interested in the engineering labor market. Special acknowledgments are extended to those participants who followed up their attendance by sending the committee additional information for consideration: Peter Cannon, vice president for research/chief scientist at Rockwell Science Center; June S. Chewning, senior manpower analyst, Department of Energy's Office of Energy Research; Robert J. Mosborg, assistant dean/director of the Engineering Placement Office, University of Illinois, Urbana-Champaign; David R. Reyes-Guerra, executive director, Accreditation Board for Engineering and Technology, Inc.; and Robert K. Weatherall, director, Office of Career Services and Preprofessional Advising, Massachusetts Institute of Technology, whose many insights were invaluable to the committee as it assembled the information provided in this report.

We hope that the efforts of these individuals will clarify the issues surrounding data needed to understand the engineering labor market and assist you in your research on engineering employment, particularly in the coming decade.

John P. McTague
Chairman

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EXECUTIVE SUMMARY

Overview

The globalization of engineering functions and the rapidly expanding pace of technological change have generated a range of policy issues of interest to educators, industrialists, and government officials at the highest levels. To arrive at wise policy decisions, policymakers must have access to information that is timely, comprehensive, and accurate.

This report summarizes the deliberations of the Office of Scientific and Engineering Personnel's Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers. Much of the information presented was discussed at a workshop convened by the Committee to decide how best to make existing data bases on engineers more complete, accurate, and compatible and to help the funding agency, the National Science Foundation (NSF), with its data-collection and analytic efforts in the 1990s.

Current data bases were evaluated in terms of their responsiveness to policy questions raised by four major issues of increasing interest to the engineering community--broadly defined to include engineers, their employers, and the institutions educating and training them:

- Occupational mobility and flow dynamics
- Technical currency
- International flows of engineers
- Role of underrepresented groups in engineering--women and members of some ethnic minority groups.

Conclusions and Recommendations

The committee reached two principal conclusions. First, current data bases are quite valuable in enabling one to understand engineering labor markets. Second, the value of existing data bases can be increased significantly for many policy purposes, without major change, by taking steps to improve the cross-correlation between them, to disseminate a larger amount of information currently unpublished but available from existing surveys, to add an element of specificity to chart areas of expertise, and to increase their longitudinal nature.

The recommendations developed by the committee are given below.

- *Existing major data bases should be continued and enhanced in order to expand our knowledge of the engineering community. Data should be readily accessible to researchers.*

- *The value of existing data bases can be enhanced by improving their longitudinal nature. Major reasons for collecting and, if currently collected, using longitudinal national data include (1) to track the retention of students, particularly women and minorities, in the engineering education pipeline, (2) to monitor occupational mobility and international flows within the engineering community, and (3) to facilitate more in-depth analyses of career patterns and the career mobility and progress of female and minority engineers. Specifically, the time frame of NSF's National Surveys of Natural and Social Scientists and Engineers should be expanded, and the feasibility of including the 1982 longitudinal postcensal sample in the sample that will be drawn for the 1990s should be investigated.*

- *Furthermore, in order to address the major issues--occupational mobility and flow dynamics, international flows, technical currency, and underrepresented groups--the committee recommends that the National Academy of Engineering convene:*

  (1) *An annual roundtable meeting at which data collectors could exchange information, coordinate their efforts, and review progress made in implementing the recommendations put forth in this report and*

  (2) *Biennial meetings of data collectors and data users--researchers, educators, employers, policymakers--to discuss data needs arising from the changing mix of policy issues.*

The committee also makes specific recommendations on the following topics, which should be among those addressed at these meetings:

- *Information on engineers generated from all current data bases should reflect recent changes both in the nature and scope of the engineering profession and in the range of activities and responsibilities of individual engineers:*

  (1) *Engineers who have entered supervisory/managerial/administrative jobs (including vice president, president, chief executive, and chairman of the board), as well as those in sales and marketing, for example, should be counted as engineers.*

  (2) *Taxonomies should be expanded beyond the identification of engineers by traditional disciplines to include identification by engineering functions. Although surveys by NSF and others include questions on work activities that are helpful and should be used more widely, there is a need for more detailed descriptions of engineering job functions, possibly including detail on the technologies and/or tools used by engineers in their job. Research and experimentation to develop taxonomies more satisfactory in this respect are necessary.*

  (3) *Field of highest degree and occupational function taxonomies should be expanded to cover emerging fields and to provide meaningful occupational disaggregations.*

(4) *Taxonomies of employment settings should be expanded to include nontraditional employers of engineers, such as accounting firms, management consulting firms, banks and investment organizations, and other service organizations, as well as small businesses and entrepreneurial companies.*

(5) *Efforts should be exerted to maximize the degree of comparability in these taxonomies to facilitate comparisons and crosswalks (see pages 9-13).*

- *The overlapping information that already exists in each data base should be exploited more fully to increase the amount of cross-correlation done; this would increase the value of all engineering employment data bases. Furthermore, the possibility of increasing the amount of overlapping information that is collected should be explored so as to improve (or refine) the degree of cross-correlation that will be possible (see pages 11-12).*

- *The usefulness of all existing engineering employment data bases for providing information on technical updating can be increased by adding data elements dealing with level of technical responsibility and level of supervisory responsibility (see pages 11-12).*

- *NSF should provide periodic cross-tabulations of occupational mobility, such as by field of highest degree and current occupational functions, controlling for years of experience. Such information can be used as a measure of adaptability, indicating the extent of movement from field of education or training to jobs requiring other engineering functions and competence (see pages 9-11).*

- *NSF Surveys of Natural and Social Scientists and Engineers should include questions dealing with both formal and informal mechanisms by which engineers maintain their technical currency. Proportion of time spent on formal and informal education and training activities should also be measured (see pages 12-14).*

- *NSF should continue its current efforts to improve data bases on foreign-born engineers, including the possibility of a regular survey of immigrants that will produce much-needed information on foreign-born engineers living and working in the United States (see pages 14-17).*

- *NSF should also continue its efforts to test the feasibility of following up foreign nationals with new U.S. degrees, both at the doctoral and other levels, who have made firm commitments to leave the United States as well as of obtaining comparative data on engineers in other countries. Information should also be collected on American engineers studying, working, or visiting abroad. The engineering personnel patterns used by multinational corporations should also be examined (see pages 14-17).*

- *Data about minorities in engineering should be collected and reported by sex (see pages 17-19).*

- *Data on women and minorities in engineering should be released in a timely manner. Such data are imperative now that there are indications of downward trends in the enrollment of women and minorities in engineering (see pages 17-19).*

In addition, special studies responding to particular information needs of the engineering community are necessary:

- *Special longitudinal studies investigating factors relating to the success or failure of women and minorities both in engineering education and in the engineering labor force should be continued (see pages 17-19).*

- *A pilot study should be conducted to develop adequate measurement techniques for utilization, technical currency, and resilience (see pages 9-14).*

- *Periodic small-scale special studies should be undertaken so as to identify (a) areas in which technology is changing rapidly and (b) newly emerging fields. Then, special studies should be conducted to study how engineers and employers are maintaining currency in those fields (see pages 12-13).*

Many of these small, special studies might best be conducted by professional societies or educational institutions. Results of such studies could be used to supplement information provided by the large data-base agencies such as the National Science Foundation and the Bureau of Labor Statistics.

1: INTRODUCTION

In the early 1980s a study of engineering education and practice--conducted by the National Research Council's Committee on the Education and Utilization of the Engineer (CEUE)--pointed out significant inadequacies in current data bases for constructing consistent portraits of the engineering community. The diverse structure and purpose of the existing data bases and the resulting definitional and methodological differences make integration of data into a comprehensive flow model of the engineering community difficult. CEUE recommended that the various public and private data-collection agencies be convened to see how best to make data on the engineering community more complete, accurate, and compatible.[1]

Within the federal government, the National Science Foundation (NSF) has the primary responsibility of collecting, analyzing, and reporting statistical information on the scientific and engineering communities and labor market. Responding to the CEUE recommendations, NSF asked the National Academy of Engineering (NAE) to convene a workshop on data needs for monitoring the engineering labor force. NAE, in turn, asked the National Research Council's Office of Scientific and Engineering Personnel (OSEP) to appoint a steering committee to plan the workshop and to write a study report.

This study is part of an ongoing effort initiated by NSF's Division of Science Resources Studies to evaluate and redesign its Scientific and Technical Personnel Data System (STPDS). The effort entails a number of activities. A panel of the Committee on National Statistics of the Research Council has been established to conduct a comprehensive review of the technical characteristics of the STPDS. In addition to the Workshop on Engineering Data Needs for the 1990s, three other workshops--on the physical sciences, the life sciences, and the social sciences--will be held. The results of these activities will be utilized in planning NSF's statistical efforts for the 1990s.

To evaluate the adequacy of existing data sources in responding to policy information needs of the 1990s, the Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers first discussed various current trends that have implications for the utilization of engineers in the next decade. The committee assumed that the globalization of economies will continue and that U.S. competitiveness will increasingly depend on the quality, talent, and innovativeness of its engineering work force. The decline in the size of the college-age population will continue until the mid-1990s. In addition, blacks and Hispanics, who usually do not enter engineering, will constitute a larger share of the talent pool. Coupled with the continuing influx of foreign nationals, the composition and the size of the engineering work force will increasingly become a national policy issue. Scientific and technological developments will continue to change rapidly. The engineering

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[1]Committee on the Education and Utilization of the Engineer, National Research Council, *Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future*, Washington, D.C.: National Academy Press, 1985.

profession will continue to adapt to rapidly changing demands by making internal adjustments--shifting talent from one engineering area to another and updating existing institutional capabilities--or by attracting personnel from other fields. However, such mobility can have consequences for the quality and productiveness of the engineering labor force. Understanding and monitoring such flows will become increasingly more important for making rational policy decisions in the 1990s.

The committee then identified four major policy issue areas that are expected to be particularly prominent in the 1990s: (1) the nature and scope of occupational mobility and flow dynamics in engineering; (2) maintaining technical currency; (3) international flows; and (4) underrepresented groups--that is, women and some minorities. Although interrelated, the committee believes that each area deals with issues that will gain in significance as globalization of the engineering enterprise continues and as questions regarding the competitiveness of the U.S. engineering work force, its social and demographic characteristics, talent pool, utilization patterns, and ability to respond to rapidly changing technology increasingly become matters of national concern.

The committee commissioned a background paper describing major data bases on engineers (see Appendix A, pages 25-60). Since the focus of the workshop was engineering practice, rather than engineering education and training, the paper provides information mostly on national and recurrent data bases on engineers in the labor market. These include NSF's National Survey of Natural and Social Scientists and Engineers (also referred to as the postcensal survey, from which the "experienced sample" is drawn); Survey of Science, Social Science, and Engineering Graduates (also referred to as the "Survey of New Graduates"); Survey of Doctorate Recipients; and Survey of Earned Doctorates and the Bureau of Labor Statistics' (BLS) Occupational Employment Survey and Current Population Survey. Membership data bases maintained by various engineering societies, such as the National Society of Professional Engineers, as well as a few smaller surveys, such as the salary surveys of Battelle and the College Placement Council, were also included. Finally, the paper includes three major educational data sources--those of the Accreditation Board for Engineering and Technology (ABET), the Engineering Manpower Commission (EMC), and the National Center for Education Statistics (NCES), each of which produces supply-related information on engineering enrollments and degrees.

The workshop convened by the study committee on March 28, 1988, brought together individuals who educate, train, and employ engineers; researchers who use the engineering data bases; and data collectors. After discussing the strengths and weaknesses of each data base, the workshop participants formed four small discussion groups, each to assess the adequacy of current engineering data sources in addressing a particular policy issue area. Each group was also charged with the task of discussing and deciding methods of achieving some consistency in the definitions, methodology, and results of major engineering data bases and the possibility of integrating them. Based on the proceedings of the workshop (see Appendix D, pages 67-77), the committee identified areas in which current data-collection efforts can be improved to meet engineering labor-market information needs of the 1990s. This report summarizes the results of the workshop and presents the recommendations of the study committee.

2: WHO IS AN ENGINEER?

It has often been noted that different data bases give quite different counts of the number of engineers in the United States. A major reason is that they use different ways of defining "engineer," depending on the purpose for which they are created, and different methods of determining who belongs in that category. For instance, the National Science Foundation's (NSF) complex screening process defines and identifies engineers based on educational credentials (at least 2 years of college), self-reported occupation (has been employed in an engineering occupation as defined by NSF; this excludes computer specialists), and/or professional identification as an engineer on the basis of total education and work experience. Missing are data on technologists, technicians, and others who may be employed in engineering positions without the educational credentials as prescribed by NSF. On the other hand, the Occupational Employment Survey conducted by the Bureau of Labor Statistics (BLS) requests all U.S. industries to provide data on the number of persons working as engineers, based on the definition for each occupation provided by BLS (this excludes sales engineers, engineering teachers, and individuals trained or educated in engineering but working in other fields, including management). The monthly Current Population Survey conducted by BLS is also occupation-specific; the surveys sent to households ask respondents to indicate the fields in which individuals are working rather than those for which they may have been educated or trained.

Both NSF and BLS secure useful information, but neither secures all that is needed when the primary focus is on the structure and dynamics of a professional field--rather than on its size--or on the flow of persons into, within, and out of that profession, or on estimating the potential or future supply. Thus, a more flexible and inclusive definition is needed to assure information on individuals who may at various times be part of the engineering labor force, though not necessarily at the time of a specific survey. In this broad sense, the engineering community includes not only practicing engineers but also retired ones; engineers who are applying their knowledge to sales, management, or related activities; individuals who are trained or educated in other fields but who are doing or are qualified to do engineering work; and other potential members of the engineering work force.

The definitions used are most worthwhile to achieve one objective--namely, to determine the size of the engineering population. However, for the purposes of this report, and generally in studying the dynamics of the engineering profession, a broad and inclusive definition is desirable. The definition of "engineer" used by the study committee is as follows:

A person having at least one of the following qualifications:

- college/university B.S. or advanced degree in an engineering program;
- membership in a recognized engineering society at a professional level;
- registered or licensed as an engineer by a governmental agency;

- current or recent employment in a job classification requiring engineering work at a professional level.[2]

[2]Committee on the Education and Utilization of the Engineer, National Research Council, *Engineering Infrastructure Diagramming and Modeling*, Washington, D.C.: National Academy Press, 1986, page 11.

3: DATA BASES AND POLICY ISSUES

Current engineering employment data bases provide answers to many policy questions. However, data gaps do exist in some areas of interest to the engineering community (see Appendix A, pages 25-60). The committee identified four major issues on which more data should be made available: occupational mobility and flow dynamics, maintaining technical currency, international flows, and underrepresented groups (women and some ethnic minorities). This chapter is structured around the committee's deliberations and discussion at the committee-sponsored workshop about those four issues.

Occupational Mobility and Flow Dynamics

Engineering is a dynamic profession, constantly changing and adapting to new conditions and demands. It is also an extremely diverse profession, involving a wide range of skills, competencies, and work settings. Engineers are now found in a variety of settings, ranging from factories, construction sites, and laboratories to the chief executive offices of multinational conglomerates.

The rate of technological change has intensified. As a consequence, emerging fields are rapidly altering the nature and practice of engineering, and the relationship between engineers and their support systems is constantly changing. While the number of engineering specialties and subspecialties is growing, there is, at the same time, greater pressure for interdisciplinary activity.

The educational system seeks to keep ahead of the rapidly changing nature of engineering work, but it is difficult to anticipate needs in fields where technology will change, or even to respond in time to those that are in early stages of development. Thus, there is a time lag between emerging fields and formalization of educational programs. Thus, adjustments to new needs are normally first made by moving existing personnel among engineering fields and between engineering and other fields, by increasingly relying on foreign engineers, and by providing inservice education or training to current employees.

The fungibility and resiliency of the engineering work force are also evident in its ability to respond to significant fluctuations in funding. For instance, it has been shown that large increases or decreases in defense spending did not result in the predicted consequences of sectoral distortion.[3] The only exception seems to be in the early 1970s, when defense cutbacks coincided with an economic recession and a decrease in college

[3]Panel on Engineering Labor Markets, Office of Scientific and Engineering Personnel, National Research Council, *The Impact of Defense Spending on Nondefense Engineering Labor Markets*, Washington, D.C.: National Academy Press, 1986.

enrollments, resulting in highly publicized hardships among doctoral graduates who had prepared for an academic career and for engineers employed in the aerospace industry.

The National Research Council's Panel on Engineering Labor Markets cited, as examples of the remarkable adjustment potential of the engineering labor market, (1) the willingness of experienced engineers, as well as of those in the engineering education pipeline, to follow the signals of the market, (2) the availability of persons trained in related areas, and (3) the willingness of employers to modify their hiring criteria (e.g., regarding prior experience) and to lay out new capital investments to increase productivity.[4] Occupational mobility, resiliency, and fungibility are matters of concern not only to the individual engineer, but also to educators, employers, and national policymakers. Information about these matters also gives the profession a picture of itself.

In determining major policy issues in the next decade, one must recognize that the rate of technological development will probably continue to accelerate. The engineering labor market will probably continue to respond to technological changes by making internal adjustments and by importing talent from other fields or sources. However, questions about the quality of the work force and mobility are closely related. It is important to know how much and what kinds of mobility exist in the engineering work force. Answers to the following questions will be essential in assessing the technological strength and competitiveness of the U.S. engineering work force and will be a vital part of the knowledge base required for sound policy formulation in the 1990s:

1. What are the numbers and characteristics of the engineering work force and its various components?

2. What are the typical career patterns of engineers in different fields? with different engineering degree levels? without engineering degrees?

3. How does the engineering profession respond to changing demand? Is the response the same in all engineering areas? What is the cost-effectiveness of education, training, and retraining?

In addition to the more traditional engineering functions, engineers often serve as salesmen, planners, and managers.

4. How skillful are the engineers in these different roles? What is the migration among roles? What are the salary differences? How many have management degrees, and does possession of those degrees make a difference? Whom do the managers manage? What are the rates of upward mobility in engineering?

5. How many annually leave engineering jobs to enter the "technical reserve pool"?[5] How many engineers return to engineering jobs from the "technical reserve pool"?

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[4]Panel on Engineering Labor Markets, *op. cit.*

[5]The technical reserve pool is comprised of individuals who are qualified to function as engineering faculty, engineers, engineering technologists, engineering technicians, or engineering support staff but who are currently outside the engineering community; it includes retirees and other unemployed individuals, people working in other fields, and those in the military. For further information, see Committee on the Education and Utilization of the Engineer, National Research Council, *Engineering Infrastructure Diagramming and Modeling*, Washington, D.C.: National Academy Press, 1986.

6. How many engineering technologists and technicians are there? What are their demographic and employment characteristics? What proportion of the engineering labor market do they represent? What are the rates of upward mobility among engineering technologists and technicians?

Presently existing major data sources in engineering are valuable in their content, approach, and diversity, as far as they go. They presumably serve the information needs and mandate of their data-collecting agencies and provide valuable information on the numbers and characteristics of engineers in the labor force. In particular, surveys following up the same cohort of engineers over a period of time (i.e., longitudinal surveys, such as the NSF's National Survey of Natural and Social Scientists and Engineers) are extremely valuable in tracing career patterns and mobility of engineers. The concerns regarding different estimates of the current engineering population can be partially alleviated by explaining clearly the definitional and methodological differences of the various data sources. There are, however, possible changes that would increase the value of current data bases by making them more comprehensive and compatible.

Existing data bases contain many of the necessary data elements that can be used as correlates or indicators of occupational mobility to answer most of the questions cited above. Both BLS and NSF data bases can be manipulated to provide estimates of the size of the technical reserve pool, rates of mobility, and so forth. However, most data-collection methods need to be expanded in order to be more responsive to recent and developing changes in the nature and scope of engineering education and practice.

First, in order to understand the dynamics of the engineering work force, we need to develop additional appropriate ways of looking at and describing engineers, including both identification by field of degree and identification by work function. Identification by function is particularly important for experienced engineers whose daily activities may no longer be closely related to their degree fields. Appropriate functional identification will increase our understanding of the effects of engineering education as well as of career flexibility, resiliency, and mobility of engineers. Moreover, such information is vital to our understanding of the supply-demand relationship in engineering. Usually, the demand for technical people, especially in the case of experienced persons and those with advanced degrees, is not simply for electrical engineers as such but for specialists in digital circuit design, semiconductor devices, optical communications, or some other specialty. This is the level at which shortages and surpluses become apparent. It is also the level at which much of the perceived migration between fields occurs.

Second, the detail level of functions or specialty lists will have to be increased to match the increasingly evolving, diverse, and, at the same time, interdisciplinary skills and activities of engineers. Engineers are utilized at different responsibility levels and play many different roles, ranging from design and production functions to sales and management, and should be identified and counted. Engineers are also employed in many diverse settings. Increasingly, small companies are generating much of the new technology in this country and the engineer/businessmen clearly are a vital part of this country's engineering work force. Their role should not be discounted just because their jobs entail more than engineering.

Although dealing with the increasingly large array of specialties within major engineering functions may present problems to NSF and BLS, without such detail, our understanding of the engineering work force will remain inadequate, will perpetuate the traditional view, and will fail to accurately reflect its dynamic nature. Therefore, if we are to establish data bases that will be suitable for the next decade or so, the current surveys must be expanded beyond the identification of traditional disciplines so that they include such engineering functions and interdisciplinary activity as systems engineering, applications/field service, consulting engineering, quality control, manufacturing/ production engineering, plant engineering, and process engineering, as well as technical marketing and sales engineering. Such information could be used as a measure of adaptability, indicating the extent of movement from field of education or training to jobs requiring new engineering functions and competence.

BLS surveys would benefit from inclusion of questions on education, such as degree fields and levels, while the NSF surveys would benefit from inclusion of more in-depth questions on function, such as technical and supervisory responsibility. However, in order to maintain the time-series value of BLS and NSF surveys, the recommended additions to already existing taxonomies should supplement rather than replace previously used categories. The inclusion of these expanded taxonomies in NSF and BLS surveys would increase the usefulness of each data base and allow researchers to develop crosswalks between the two data bases in order to obtain a more comprehensive picture of the engineering work force.

Finally, an important component of the engineering work force is comprised of those who obtained their competence by paths other than formal education in engineering. NSF data bases already collect much information on all practicing engineers, but there has been little use of this resource to enumerate and describe the characteristics of engineers without formal science or engineering education. Data from both NSF and BLS data bases should be utilized more extensively to determine the number, characteristics, and career patterns of engineers without engineering or science backgrounds.

Some professional societies include more detailed utilization questions in their surveys of membership than do BLS or NSF in their nationwide surveys of engineers and scientists. For instance, in the National Engineering Utilization Survey, the Engineering Manpower Commission (EMC) asked questions dealing with "present supervisory responsibility," including supervision of nontechnical personnel, nonprofessional technical personnel, professional engineering personnel, and different management levels. The question regarding "the level of technical responsibility of present job" included items ranging from "prescribed procedures requiring no previous knowledge" to "pioneering work-international authority." Occupational taxonomies used in such surveys also tend to be more detailed and current than those used by national data collectors. A closer cooperation between governmental data-collection agencies and professional societies might result in collection of information that is more useful and has greater value.

Maintaining Technical Currency

Engineering plays a crucial role in maintaining the nation's defense capability, contributes to its economic competitiveness in world markets, enhances its quality of life, and provides the technical means by which its national resources are protected. Any decrease in the technical currency of the U.S. engineering work force would have direct negative consequences on the nation's economic and social health.

In the rapidly changing world of engineering, a major concern to employers is maintaining the technical competence of their employees. Professional societies provide educational programs to keep the engineering profession healthy and up-to-date. Educational institutions, both not-for-profit and for-profit, are also interested in the needs for technical updating in different engineering fields. First, they are one of the major providers of such education programs. Second, information about technical needs is crucial for maintaining the currency of educational curricula and programs and for attracting students as well as for achieving the crucial balance between the core engineering curriculum and other courses that facilitate the adaptability and resiliency of the engineering work force.

There is limited but consistent evidence that "misutilization" of engineers is a major contributing factor to their obsolescence.[6] Work assignments that do not challenge engineers to acquire knowledge of the latest developments result in quicker obsolescence. Sometimes introduction of new technology produces almost instant obsolescence: for example, computers are rapidly displacing drafting technologists and technicians.

Because of rapidly changing technology, there is growing emphasis on career-long education and professional development in every field of engineering. It is essential to know how different engineers at different levels with different functions are keeping themselves current. Specifically,

1. What are the utilization patterns of engineers in different fields? How are they affected by new technologies, such as computer-aided design?

2. What is the extent of systematic updating throughout the engineering profession? How well do engineers maintain their technical currency?

3. What are the most effective ways to improve resilience in the engineering work force?

4. What is the scope, nature, and effectiveness of available educational programs in engineering?

Current data bases collect little information on technical updating. The committee believes that several actions designed to find ways of securing such information and to improve the usefulness of some existing data bases should be pursued.

Interactions with colleagues, reading periodicals, and other informal means are as crucial in maintaining technical currency as is participating in formal education programs. Yet information is more readily available on formal than on informal education programs. For instance, questions on career-long education in NSF's National Surveys of Natural and Social Scientists and Engineers include courses given at the employer's training facility, at continuing education centers, in professional meetings, or by professional societies and the armed forces. However, the usefulness of this longitudinal survey could be increased by the addition of questions concerning additional informal means of maintaining one's

[6]American Association of Engineering Societies, *Toward the More Effective Utilization of American Engineers: The National Engineering Utilization Survey*, New York: Engineering Manpower Commission, 1986.

technical currency.[7] Clearly, measurement problems will need to be resolved before effectiveness of such education programs can be assessed. Professional societies are encouraged to include in their surveys detailed questions dealing with technical currency and various measures of effectiveness of several education programs in order to supplement the information collected from the ongoing and cumulative surveys of NSF.

International Flows

Based on estimates provided by a recent study by the National Research Council, nearly 2 in 10 engineers in the United States in 1982 were foreign-born. The same year, foreign-born engineers accounted for 36 percent of the new Ph.D.s entering the American engineering labor force. The dependence on foreign-born engineers appears to be greatest in academic institutions. In 1982, foreign-born engineers constituted nearly 3 in 10 of all engineers employed in American universities. Toward the mid-1980s, over one-half of engineering assistant professors under the age of 35 were noncitizens. Noncitizens represented over 60 percent of engineering postdoctorates in 1985, and over 40 percent of all full-time graduate enrollments in engineering.[8] The preponderance of foreign-born engineering faculty and students has led to problems in communication and to concerns regarding the changing culture of engineering departments.[9] Some institutions have now imposed admission ceilings for foreign students. Some are concerned that if foreign-born engineers continue to receive larger shares of advanced engineering degrees, the United States will find an inadequate supply of U.S. citizens for its national security missions.[10]

During the next decade it will become increasingly more important to monitor and study the effects of the influx of foreign nationals into the U.S. engineering community and the outflow of those who are U.S.-educated. As the globalization of the engineering enterprise continues, ties to engineering in foreign countries will become more important to the health of U.S. engineering as well as to the general health of the U.S. economy. The flow of engineering jobs and responsibilities across international borders has far-reaching consequences that are only partially understood. As the dependency of the United States on foreign engineering talent continues to grow, better information will be needed to make policy decisions regarding the import and export of engineering services.

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[7] See, for instance, Robert C. Dauffenbach and Michael G. Finn, *Employer Provided Training and the Issue of Quality in the Engineering Work Force*, paper prepared for the Joint National Meetings of the Operations Research Society and the Institute of Management Science, November 1985. Dauffenbach and Finn examined the participation patterns of engineers in career-long education programs, utilizing data from the 1982 Survey of Natural and Social Scientists and Engineers, and found that training not provided by employers had no apparent effect on salaries. This study, however, did not evaluate the effects of informal mechanisms of education because of the lack of data. *See also* American Association of Engineering Societies, *Toward the More Effective Utilization of American Engineers: The National Engineering Utilization Survey*, New York: Engineering Manpower Commission, 1986, for another discussion of the effects of continuing education on salaries.

[8] Committee on the International Exchange and Movement of Engineers, National Research Council, *Foreign and Foreign-Born Engineers in the United States: Infusing Talent, Raising Issues*, Washington, D.C.: National Academy Press, 1988.

[9] Elinor G. Barber and Robert P. Morgan, "The impact of foreign students in engineering education in the United States," *Science* 236 (April 3), pp. 33-37.

[10] Glenn W. Kuswa, "Effects of foreign nationals on federally supported laboratories," in Committee on the International Exchange and Movement of Engineers, *Foreign and Foreign-Born Engineers in the United States: Infusing Talent, Raising Issues*, Washington, D.C.: National Academy Press, 1988, pp. 147-162.

Although the number of foreign-born engineering students and professionals can be estimated from various sources, there are major data gaps in coverage and in the level of detail essential for some decisions. Questions of particular concern include:

1. How many and what types of foreign engineers enter, leave, or stay in the engineering work force of the United States?

2. From which countries do foreign engineers come? What factors promote the flow of foreign engineers to the United States?

3. How many American engineers actually emigrate to foreign countries? How many make professionally related short-term or long-term visits abroad? In which disciplines? For how long? To which countries do American engineers go? What factors promote the flow of American engineers to foreign countries?

4. What is the nature of technical flows within multinational corporations?

In general, there is fair to good information about engineers who get degrees in the United States and then stay here, but much less is known either about those who get degrees and leave the United States or about those migrating to the United States with engineering degrees earned in other countries. There is also very little information about American engineers who study or work abroad.

Regarding the first set of questions, the existing data bases provide more information on the number of foreign recipients of U.S. degrees than on those already in the U.S. labor market and more regarding Ph.D. recipients than master's or bachelor's degree holders. There are good estimates of foreign Ph.D. engineers with new U.S. degrees. The Survey of Earned Doctorates provides statistics on the employment plans of new doctorate recipients each year. For instance, results of the most recent Survey indicate that 58.1 percent of the foreign-born engineers receiving U.S. doctorates planned to stay in the United States in 1986 (this includes 82.1 percent, or 151, of the 184 holding permanent visas and 53.1, or 455, of the 878 holding temporary visas).[11] Among other data sources on engineering doctorates, Michael Finn, for example, used Social Security tax information to produce independent estimates of stay rates of foreign Ph.D.s and concluded that over 60 percent of recipients of U.S. engineering doctorates in 1980 and 1981 were working in the United States in 1982 [12]

Detailed information on foreign-born engineers with bachelor's or master's degrees is more difficult to find. Several organizations--such as the National Science Foundation, National Center for Education Statistics, and Engineering Manpower Commission--provide data on the number of new graduates who are foreign nationals on temporary visas; however, there are no adequate recurrent data on the stay rate of such graduates. Postcensal surveys can be used to estimate stay rates; but because of the relatively small numbers involved, results tend to be of questionable reliability. Currently, there appears to be no easy method to get better data on the stay rate of foreign engineers with master's degrees or baccalaureates.

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[11]See, for example, Susan L. Coyle, *Summary Report 1986: Doctorate Recipients from United States Universities*, Washington, D.C.: National Academy Press, 1987.

[12]Michael G. Finn, *Foreign National Scientists and Engineers in the U.S. Labor Force, 1972-1982*, Oak Ridge, TN: Oak Ridge Associated Universities, June 1985.

Information is also needed on foreign engineers working in the United States without a U.S. degree. Using the postcensal survey of 1982, Finn estimated that foreign nationals with non-U.S. degrees constituted about one-fifth of all immigrant engineers in 1981.[13] However, this estimate cannot be updated until the 1992-93 postcensal survey.

Although existing data sources provide good information on the numbers of new foreign engineering graduates, there is very little information on their stay rates and career patterns. To improve the estimates of foreign inflows into the U.S. engineering labor force, NSF is currently taking steps to explore the cost and effectiveness of a survey of immigrants, to be conducted on a regular basis. That survey would be desirable. Another possibility is a survey of employers to determine the characteristics and contributions of foreign engineers employed in American industry.

Almost no quantitative information on the career patterns of U.S.-trained foreign nationals who return to their home countries exists. Many believe that U.S.-trained foreign engineers are important contacts, providing techno-economical links between the United States and multinational engineering companies while also promoting and contributing to technology transfer. At present, no data bases can be used to test such contentions. Clearly, a survey of U.S.-trained foreign engineers no longer living in the United States would be costly. However, since NSF surveys of recent graduates, beginning in 1986, asked respondents to provide their non-U.S. addresses, the conduct of follow-up surveys of foreign graduates who return to their home countries should be possible. Response rates of foreign engineers who have returned home will probably be lower than average; nevertheless, the feasibility of acquiring data in this manner should be investigated.

Finally, the engineering community would benefit from more and better data on engineers in other countries. NSF has ongoing efforts in this area: for example, it has a contract with the U.S. Bureau of the Census to obtain census tapes from a number of foreign countries and to tabulate data that are as close as possible in definition to U.S. data on engineers and scientists. The committee endorses such efforts.

Regarding the second set of questions, there is no regularly published information on the country-of-origin of engineers in the United States, although the U.S. Immigration and Naturalization Service collects such information on immigrant engineers and the Institute of International Education does the same for foreign engineering students in the United States. Country-of-origin data can be obtained from the Survey of Doctorate Recipients and from the postcensal surveys. The latter, however, requires special tabulations from the Bureau of the Census, as country-of-origin information is suppressed on the public user tapes. Moreover, these data sources provide enumerative and descriptive information only and do not permit identification of factors that promote the flow of scientists and engineers to the United States. A few special studies have been conducted to determine reasons for staying in the United States: findings suggest that income differentials, professional opportunities, and work conditions are important determinants of immigration of professionals to the United States, along with a number of political and social considerations.[14] Further, U.S. immigration policy and its subsequent changes also exert significant influence on immigration patterns of foreign professionals to the United States.[15]

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[13]Finn, *op. cit.*

[14]See, for example, Wei-Chiao Huang, "A pooled cross-section and time-series study of professional indirect immigration to the United States," *Southern Economic Journal* (July 1987), pp. 95-109.

[15]Vinod Agarwal and Donald Winkler, "Migration of professional manpower to the United States," *Southern Economic Journal* (January 1984), pp. 814-830.

Regarding the third set of questions, most of what we know about the flow of U.S. engineers to foreign countries currently comes from very limited and inadequate data or from anecdotal sources. The Survey of Earned Doctorates contains a question on intention to study abroad after graduation. Statistics show that each year fewer than 1 percent of new engineering doctorates elect to study abroad.[16] A special follow-up survey of this small group of engineering doctorates might shed much-needed information on the reasons and actual benefits of postdoctoral study in foreign countries.

Current data sources provide almost no information on American engineers working abroad. NSF experimented with a new set of questions for the 1987 Survey of Doctoral Scientists and Engineers, dealing with trips abroad for three or more months. If these questions prove to be useful, similar questions should be included in the Survey of Recent Graduates and in the next generation of postcensal surveys.

Other potential data sources remain largely untapped. For instance, national laboratories and firms funded by the Department of Defense and the Department of Energy with national security work keep track of travel abroad. Information on U.S. citizens traveling to countries that require a visa can be obtained from foreign consulates, although work requiring short stays may be accomplished on a travel, rather than a work, visa. U.S. companies may also keep track of their employees' activities abroad. Information on U.S. engineers working abroad is but one useful and essential component of a data system on international flows that should be developed and collected on a regular basis.

The international movement of engineers contributes to the exchange of information and has important consequences for technical development in the United States and for global competitiveness. International technology transfers in such fields as magnetic fusion and high-energy physics research are often cited as models for mutual benefit among nations.[17] The increasing globalization of the engineering enterprise dictates that in the 1990s national engineering data sources have the capability to track international inflows and outflows of the engineering community effectively and precisely.

Underrepresented Groups: Women and Some Ethnic Minorities

From the mid-1970s to the early 1980s, the number of women and minorities in engineering grew. Their increased participation, coupled with dramatic increases in the number of foreign students, masked the continuing decline in the proportion of traditional engineering students--that is, white males.

Today, however, women and ethnic minorities, with the exception of Asian Americans, continue to be underrepresented in engineering. Moreover, there are signs that their enrollments have already peaked and are beginning to decline, raising serious questions about the shrinking talent pool of engineers. It is estimated that between 1970 and 1983, the number of women engineers tripled.[18] Despite these increases, NSF reports that in 1986, women comprised only about 4 percent of the total engineering work force of over

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[16]Committee on the International Exchange and Movement of Engineers, *op. cit.*

[17]*Ibid.*

[18]Committee on the Education and Utilization of the Engineer, National Research Council, *Engineering Employment Characteristics*, Washington, D.C.: National Academy Press, 1985.

2.4 million.[19] Blacks, Hispanics, and American Indians continue to be underrepresented in the engineering work force. Estimates of the number of blacks, for instance, range from 2 to 3 percent of the total engineering work force, while they represent nearly 12 percent of the general population.

The committee discussed various studies dealing with women and minorities in engineering and the adequacy of available data sources in responding to the following questions:

1. What are the numbers and characteristics of women and minorities who enter engineering education and practice? What are the numbers and characteristics of technically qualified women and minorities who select nontechnical curricula? What are the numbers, characteristics, and attitudes of women and minorities who drop out of engineering--either before or after achieving an engineering degree?

2. What percentage of women and minorities holding engineering bachelor's degrees pursue graduate education in engineering? What factors influence their decisions? What are the structural barriers to their pursuit of graduate education in engineering?

3. What are the utilization patterns of women and minority engineers, including reentry women and minorities, as compared to white males by field, industry, and type of activity? What are their career patterns? What factors determine their career patterns? How do these factors differ from those influencing the career patterns of white males?

Some of the data needed to answer these questions already exist. Enumerative data on female and minority engineers are usually considered to be good but not mutually exclusive. Demographic data on scientists and engineers are routinely reported: for example, *Women and Minorities* is published annually by NSF and *Science Indicators* (recently retitled, *Science and Engineering Indicators*) is published biennially by the National Science Board. Enrollment and degree information is also routinely reported by the National Center for Education Statistics and the Engineering Manpower Commission. However, most of the enumerative information on women and minorities is reported separately; thus, there is not a separate analysis of minority women. Similarly, institutional data bases do not usually report minority data by sex. Cross-tabulations by sex and by race can be obtained from individual data bases but usually are not presented as such because of small cell sizes.

In general, studies providing descriptive and analytic information on the participation of women and minorities are more readily available for the education than for the labor market domain, more for women than for minorities, and more for doctorate recipients than for holders of other degrees.

NSF's data collection is most appropriate for monitoring progress in the participation of women and minorities in engineering and in deepening our understanding of their experience and treatment once they enter the engineering work force. For instance, the

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[19]National Science Foundation, *U.S. Scientists and Engineers: 1986* (NSF 87-322), Washington, D.C.: U.S. Government Printing Office, 1987.

National Research Council's Committee on the Education and Employment of Women in Science and Engineering examined extensively the Surveys of Earned Doctorates and of Doctorate Recipients in order to document career patterns of female doctorates in academe, industry, and government.[20] Using NSF's 1972 and 1978 Surveys of Natural and Social Scientists and Engineers, Michael Finn examined the differential effects of experience, training, and education on salaries of male and female scientists.[21] To understand their participation in science and engineering, NSF oversampled both women and minorities in its drawing of the 1982 postcensal survey population. However, given the small number of female scientists and engineers in these samples, it has been difficult to analyze utilization patterns in detail--for example, in different subspecialty areas or by different occupational functions. The even smaller numbers of minorities preclude any but the most general level of analysis. In many occupations the sample can not be expanded to include more women or underrepresented minorities because questionnaires have already been sent to all who completed the 1980 Census of Population survey forms.

These concerns indicate the limitations of the national data bases and suggest the need for supplementary approaches such as smaller "case study" projects that focus directly on issues pertaining to the participation and utilization of women and minorities in engineering.

[20] Committee on the Education and Employment of Women in Science and Engineering, National Research Council, *Climbing the Academic Ladder: Doctoral Women Scientists in Academe*, Washington, D.C.: National Academy of Sciences, 1979; *Career Outcomes in a Matched Sample of Men and Women Ph.D.s: An Analytic Report*, Washington, D.C.: National Academy Press, 1981; *Climbing the Ladder: An Update on the Status of Doctoral Women Scientists and Engineers*, Washington, D.C.: National Academy Press, 1983.

[21] Michael G. Finn, *Training, Work Experience, and the Earnings of Men and Women Scientists*, Oak Ridge, TN: Oak Ridge Associated Universities, 1981. See also Aline Quester, *Men and Women in Science and Engineering Occupations*, Alexandria, VA: Center for Naval Analysis, 1984.

4: CONCLUSIONS AND RECOMMENDATIONS

Current data bases in engineering are valuable in their content, approach, and diversity, as far as they go. Concerns regarding the divergence in results produced by different data bases, such as the labor-market estimates of the National Science Foundation and the Bureau of Labor Statistics, could be partially alleviated by clear explanations of differences in definitions and methodologies that lead to such differences. However, these differences may make difficult, if not impossible, the comingling of data from the various data bases to achieve broader goals and deeper understandings of the engineering community and its workings.

Engineering data basesserve a wide variety of purposes. Since each different data base seems to serve effectively the purposes and information needs for which it was designed, integration of all current engineering data bases into one major data source on engineering does not appear to be either desirable or feasible. It should be noted that the usefulness of the BLS and NSF data bases in engineering comes from their estimates of the number of engineers as well as from the descriptive and analytic information that they produce about the engineering labor force. In particular, NSF's data system is very valuable in providing descriptive information about the characteristics of the engineering work force. Although it is important for supply and demand projections to have accurate information about the size of the engineering work force, the committee recognizes that definitional and labeling differences will result in different counts. Neither the single count used by BLS nor the algorithms used by NSF will do justice to the complex and dynamic reality of the engineering community.

Thus, the committee urges that immediate steps be taken to implement three of its recommendations:

1. Existing major data bases should be continued and enhanced in order to expand our knowledge of the engineering community. Data should be readily accessible to researchers.

2. The value of all existing data bases can be enhanced by improving their longitudinal nature. Major reasons for collecting and, if currently collected, using longitudinal national data include (1) to track the retention of students, (2) to monitor occupational mobility and international flows within the engineering community, and (3) to facilitate more in-depth analyses of career patterns and the career mobility and progress of female and minority engineers. Specifically, the time frame of NSF's National Surveys of Natural and Social Scientists and Engineers should be expanded, and the feasibility of including at least some of the 1982 longitudinal postcensal sample in the sample that will be drawn for the 1990s should be investigated.

3. The National Academy of Engineering should convene regular meetings at which engineering data bases will be addressed:

- An annual roundtable meeting at which data collectors could exchange information, coordinate their efforts, and review progress made in implementing the recommendations put forth in this report and

- Biennial meetings of data collectors and data users --researchers, educators, employers, policy makers --to discuss data needs arising from the changing mix of policy issues.

The committee recognizes that its recommendations involve a range of costs as well as of difficulty. Nonetheless, because of the importance to the engineering community of the data collected and the resulting analyses by the various organizations and agencies cited in this report, the committee urges that steps be taken to implement the recommendations in the following order:

Most Important

4. Information on engineers generated from all current data bases should reflect recent changes both in the nature and scope of the engineering profession and in the range of activities and responsibilities of individual engineers:

- Engineers who have entered supervisory/managerial/administrative jobs (including vice president, president, chief executive, and chairman of the board), as well as those in sales and marketing, for example, should be counted as engineers.

- Taxonomies should be expanded beyond the identification of engineers by traditional disciplines to include identification by engineering functions. Although surveys by NSF and others include questions on work activities that are helpful and should be used more widely, there is a need for more detailed description of engineering job functions, possibly including detail on the technologies and/or tools used by engineers in their jobs. Research and experimentation to develop taxonomies more satisfactory in this respect are necessary.

- Field of highest degree and occupational function taxonomies should also be expanded to cover emerging fields and to provide meaningful occupational disaggregations.

- Taxonomies of employment settings should be expanded to include nontraditional employers of engineers, such as accounting firms, management consulting firms, banks and investment organizations, and other service organizations, as well as small businesses and entrepreneurial companies.

- Efforts should be exerted to maximize the degree of comparability in these taxonomies to facilitate comparisons and crosswalks (see pages 9-13).

5. The overlapping information that already exists in each data base should be exploited more fully to increase the amount of cross-correlation done; this would increase the value of all engineering employment data bases. Furthermore, the possibility of increasing the amount of overlapping information that is collected should be explored so as to improve (or refine) the degree of cross-correlation that will be possible (see pages 11-12).

6. NSF should continue its efforts to test the feasibility of following up foreign nationals with new U.S. degrees, both at the doctoral and other levels, who have made firm commitments to leave the United States as well as of obtaining comparative data on engineers in other countries. Information should also be collected on American engineers studying, working, or visiting abroad. The engineering personnel patterns used by multinational corporations should also be examined (see pages 14-17).

7. NSF should provide periodic cross-tabulations of occupational mobility, such as by field of highest degree and current occupational functions, controlling for years of experience. Such information can be used as a measure of adaptability, indicating the extent of movement from field of education or training to jobs requiring other engineering functions and competence (see pages 9-11).

8. NSF Surveys of Natural and Social Scientists and Engineers should include questions dealing with both formal and informal mechanisms by which engineers maintain their technical currency. Proportion of time spent on formal and informal education and training activities should also be measured (see pages 12-14).

9. The usefulness of all existing engineering employment data bases for providing information on technical updating can be increased by adding data elements dealing with level of technical responsibility and level of supervisory responsibility (see pages 11-12).

Very Important

10. NSF should continue its current efforts to improve data bases on foreign-born engineers, including the possibility of a regular survey of immigrants that will produce much-needed information on foreign-born engineers living and working in the United States (see pages 14-17).

11. Special studies investigating factors relating to the success or failure of women and minorities both in engineering education and in the engineering labor force should be continued (see pages 17-19).

12. A pilot study should be conducted to develop adequate measurement techniques for utilization, technical currency, and resilience (see pages 9-14).

13. Periodic small-scale special studies should be undertaken so as to identify (a) areas in which technology is changing rapidly and (b) newly emerging fields. Then, special studies should be conducted to study how engineers and employers are maintaining currency in these fields (see pages 12-13).

Important

14. Data about minorities in engineering should be collected and reported by sex (see pages 17-19).

15. Data on women and minorities in engineering should be released in a timely manner. Such data are imperative now that there are indications of downward trends in the enrollment of women and minorities in engineering (see pages 17-19).

The committee sees a real need for better communication and coordination among the federal agencies collecting information about the engineering labor force and between those data collectors and others with more proscribed samples or interests. While the committee recognizes that some of the existing engineering human resource data bases have already implemented various of the recommended actions, it believes that incorporating changes that will make them more comprehensive and compatible will also facilitate crosswalks across major data bases, significantly increasing their usefulness to researchers interested in labor-market conditions for engineers and in engineering practice, and will produce valuable information upon which rational policy decisions can be made, both at governmental and institutional levels. The committee's recommendations respond to major concerns of the engineering community. It is hoped that action will be taken on each of them in the near future.

APPENDIX A

BACKGROUND PAPER
by Engin Inel Holmstrom

Introduction

In the early 1980s, a major study on engineering education and practice was conducted by the National Research Council's Committee on the Education and Utilization of the Engineer (CEUE). That study, partially supported by funds from the National Science Foundation (NSF), concluded that currently available data bases are inadequate for making historical comparisons or constructing consistent portraits of the engineering community and recommended a more comprehensive and consistent set of data, available on an annual basis, for tracking and assessing the supply and utilization of engineers. CEUE recommended that (1) the data-collection agencies use common definitions as well as flow diagrams to identify and collect consistent information on different segments of the engineering community and (2) the various public and private data-collection agencies be convened to see how best to make data on the engineering community more complete, more accurate, and more compatible.[1]

Responding to the CEUE recommendation, NSF funded a workshop on data needs for monitoring engineering labor-market conditions, convened by a study committee of the Research Council's Office of Scientific and Engineering Personnel (OSEP). Issues to be addressed by the Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers include the definitional inconsistencies and methodological incompatibilities of existing data bases, extension or integration of data bases to reduce current information gaps, and future data needs. The results will help NSF to plan for its data collection and analytical efforts in the 1990s.

This background paper has been prepared to assist workshop participants in their deliberations on engineering data needs. First, it summarizes the CEUE findings and conclusions about data needs and availability, including the engineering manpower flow diagram developed to identify different components and data needs of the engineering community (Appendix A-1). Second, data sources, including the ones used by the CEUE, are presented (detailed descriptions of each data base are reported in Appendix A-2), and methodological differences resulting in definitional and classification problems are discussed. Finally, the paper presents a number of issues designated by the Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers as the major labor-market questions of the 1990s and lists available data bases that could be used to analyze them.

The focus of the workshop is not education per se but, rather, engineering practice, although there are many educational questions that also require better and more comprehensive data collection. Further, many of the issues faced by the engineering educational community have direct bearing on the future of engineering employment. However, the workshop participants are invited to concentrate on questions that contribute to our understanding of the practice of engineering. Educational data and issues should be considered only in terms of their impact on the scope and composition of the engineering supply.

Findings and Recommendations of the Committee on the Education and Utilization of the Engineer

Two CEUE panels dealt specifically with labor-market issues. The Panel on Engineering Employment Characteristics was charged with (1) developing an understanding of the employment patterns and demographic and educational characteristics of engineers, technologists, and technicians and (2) determining how these patterns have changed or were likely to change with time. Using Bureau of Labor Statistics (BLS) data, that panel found that the engineering work force had grown steadily, doubling its numbers to more than 1.5 million between 1960 and 1982. In addition, there were 750,000 computer specialists and 1.1 million engineering technicians in 1982. The panel was disturbed by the fact that estimates of the number of engineers ranged from 1.2 million (BLS) to more than 1.9 million (NSF).

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[1]Committee on the Education and Utilization of the Engineer, *Engineer Education and Practice in the United States: Foundations for our Techno-Economic Future*, Washington, D.C.: National Academy Press, 1985

There were also numerous inconsistencies in the numbers of different segments of the engineering community. The panel concluded that these inconsistencies made it difficult to develop either quantitative or qualitative descriptions of the engineering community and that without standard measurement criteria, these differences would be impossible to reconcile.[2]

The CEUE Panel on Infrastructure Diagramming and Modeling discussed more fully the strengths and weaknesses of the data collection system as a whole.[3] That panel studied the structure and dynamics of the engineering community, including underlying driving forces and factors influencing both entrance into and exit from that community. The panel developed a flow diagram to present graphically the complex flows and interactions of the people who make up the engineering community and to help identify different components of the system for which separate information is needed (Appendix A-1). The following stocks and flows were identified:

- Entry pool, consisting of students in secondary education, foreign students, and returning adults;
- Postsecondary education pool, consisting of B.S./M.S. engineering students, B.S./M.S. science/math students, B.S./M.S. technology students, B.A./M.A. nontechnology students, collegiate below-B.S. technical students, and collegiate below-B.S. nontechnical students;
- Ph.D. pool, consisting of engineering Ph.D. students, science/math Ph.D. students, foreign Ph.D. students;
- Engineering community employment pool, including engineering faculty, engineering pool, technology pool, and technician pool;
- Transfers to staff support pool or to other positions (e.g., sales or managerial);
- Exit from the engineering community due to death, disability, emigration; transfers to other jobs; and foreign workers returning to their home countries;
- Temporary exit to technical reserve pool.

In collecting engineering manpower data, CEUE recommended that the following definitions be used by all data-collection agencies:

Engineering Business, government, academic, or individual efforts in which knowledge of mathematical, physical and/or natural sciences is employed in research, development, design, manufacturing, systems engineering, or technical operations with the objective of creating and/or delivering systems, products, processes, and/or services of a technical nature and content intended for use.

Engineering Community People meeting at least one of the following conditions:

- Actively engaged in engineering, as defined above;
- Actively engaged in engineering education;
- Qualified as an engineer, engineering technologist, or engineering technician, as defined below, and actively engaged in such engineering support functions as engineering management or administration, technical sales, or technical product purchasing;
- Qualified as an engineer, engineering technologist, or engineering technician, as defined below, who was but is not now actively engaged in engineering, engineering education, or engineering support.

Engineer A person having at least one of the following qualifications:

- College/university B.S. or advanced degree in an accredited engineering program;

[2]Committee on the Education and Utilization of the Engineer, *Engineer Employment Characteristics*, Washington, D.C.: National Academy Press, 1985.

[3]Committee on the Education and Utilization of the Engineer, *Engineering Infrastructure Diagramming and Modeling*, Washington, D.C.: National Academy Press, 1986.

- Membership in a recognized engineering society at a professional level;
- Registered or licensed as an engineer by a governmental agency;
- Current or recent employment in a job classification requiring engineering work at a professional level.

Engineering Technologist A person having at least one of the following qualifications:

- A bachelor's degree from an accredited program in engineering technology;
- Current or recent employment in engineering work, but lacking the qualifications of an engineer as defined above.

Engineering Technician A person having at least one of the following qualifications:

- A degree or certificate from a one- to three-year accredited technical program;
- Current or recent employment in engineering work, but lacking the qualifications of an engineer as defined above and at a lower job level than that of an engineering technologist.

These definitions appear to be broad and flexible enough not to cause major changes in definitions currently used by major data-collection agencies. However, the definition of the overall engineering community clearly points out inadequacies in the existing data-collection system. Specifically, CEUE found that data are relatively incomplete on staff support, technical reserve, and technician pool as well as on flows out of engineering due to retirement, death, etc. Further, information is very limited on immigration/emigration, geographical mobility, reentering adults, and community college graduates.

Data Bases on Engineers

The following is a brief description of the organizations that manage data bases on engineering manpower (see Appendix A-2 for detailed descriptions). Some of these organizations collect data only on engineers (e.g., Engineering Manpower Commission) while others have broader target populations (e.g., Bureau of the Census) from which information on engineers can be extracted. In between are the data bases managed by NSF, whose data-collection efforts focus on scientific and technical human resources.

Overview

The Accreditation Board for Engineering and Technology (ABET) has maintained since 1936, when accreditation first began in engineering, all the data on educational institutions and programs generated through the accreditation process. ABET conducts annual analyses of the results of accreditation action in engineering, engineering technology, and related areas. In particular, ABET data deal with the quality and status of engineering education.

The Engineering Manpower Commission (EMC) of the American Association of Engineering Societies maintains a data base on engineering and technology enrollments and degrees based on annual surveys of educational institutions. The survey population for *engineering* enrollments and degrees is quite comprehensive and includes over 300 institutions of higher education that award at least a bachelor's degree in engineering. The *technology* survey, on the other hand, is somewhat less comprehensive. Information is collected by sex, ethnicity, citizenship, and a number of educational variables. No information is collected on pre-engineering enrollments in 2-year institutions.

EMC also collects base salary information annually from a comprehensive sample of employers. It also conducts biennial surveys of salaries of engineering faculty. Salary information is provided by type of school and by academic rank. Since 1986, all EMC enrollment and degree data are available in PC machine-readable format.

The American Society for Engineering Education (ASEE) conducts an annual survey of engineering college research and graduate study, published in the spring as the Engineering College Research and Graduate Study issue of Engineering Education. Entries from over 200 schools provide information for prospective students as well as data on faculty and student numbers, degrees, research expenditures, and separately funded laboratories. Detailed indexes list fields of study and areas of research. ASEE also conducts annual or biennial surveys of engineering and engineering technology faculty and graduate students. The survey population is comprehensive and includes most engineering schools.

The National Society of Professional Engineers (NSPE) conducts annual engineering salary surveys of its membership. Since NSPE membership tends to be older than engineers in general, the survey results are not readily generalizable to the engineering population, unless cross-tabulations are run by age.

The National Science Foundation's Division of Science Resources Studies designs, conducts, and supports surveys collecting information on scientific and technical personnel, funding, and inputs/outputs to the science and technology enterprise. NSF maintains the Scientific and Technical Personnel Data System, which comprises three surveys and a computer-based model: the National Survey of Natural and Social Scientists and Engineers (often referred to as the "Experienced Sample"); the Survey of Doctorate Recipients; and the Survey of Science, Social Science and Engineering Graduates (also called the "Survey of New Graduates"). While each survey provides information on a select portion of the total S/E population, the model--the Science and Engineering Tabulating Model--combines the results of the Experienced Sample with that of the Survey of New Graduates to produce national estimates of the total stock of engineers and scientists in the United States.

NSF's very complex screening process defines and identifies engineers based on educational credentials (at least 2 years of college), self-reported occupation (has been employed in an engineering occupation as defined by NSF; this excludes computer specialists), and/or professional identification as an engineer on the basis of total education and work experience. Missing are data on technologists, technicians, and others who may be employed in "engineering" positions without the educational credentials as prescribed by NSF.

Other regular data-collection activities of NSF include the Survey of Earned Doctorates (results of which are incorporated into the Doctorate Records File maintained by the National Research Council) and Survey of Graduate Science and Engineering Students and Postdoctorates. NSF also uses data from the Immigration and Naturalization Service to assess annual flows of foreign scientists and engineers.

The National Center for Education Statistics (NCES), Department of Education, through (1) Fall Enrollment and Compliance Report and (2) Degrees and Other Formal Awards Conferred, has provided information annually on enrollments and degrees conferred in higher education institutions in the United States. These data have been reported by sex of student, control of institution (public, private), and discipline specialty. In recent years, cross-tabulations by discipline specialty have been excluded from published reports but can be obtained from the Center. NSF publishes field data on earned degrees from the NCES' "degree" series.

NCES is currently expanding its data base to include over 13,000 postsecondary institutions. It has also added two new surveys to its data base: one of faculty and one on student finance.

The Bureau of the Census, Department of Commerce, conducts the Decennial Census of U.S. population. Data files include detailed demographic, educational, and employment information. NSF's Experienced Sample is drawn from the Decennial Census.

The Bureau of Labor Statistics (BLS) conducts the Occupational Employment Survey (OES) involving all U.S. industries. NSF provides partial support to cover S&E fields. This survey collects data on the number of persons working as "engineers." Definitions for each occupation are provided to respondents. The definition of "engineer" excludes sales engineers and engineering teachers, but data are collected separately on these two occupations. Workers in all fields of training (or work) whose duties are primarily managerial are counted as managers. A 3-year cycle is needed to cover the entire U.S. industrial sector. The Current Population Survey (CPS), based on monthly household structured interviews, provides employment statistics for the U.S. population.

Data from the three survey waves are aggregated biennially by BLS' Office of Economic Growth and Employment Projections. Counts of engineering jobs provided by industry are integrated with counts of self-employed engineers (obtained from the CPS) and form the basis of the Industry-Occupational Matrix, used in estimating base-year numbers of engineers and in projecting employment.

Battelle conducts annual salary surveys of 1,254 R&D centers in firms having over 12,000 employees. The data are reported from employee payroll records. No demographic information is collected.

The College Placement Council (CPC) also conducts annual salary surveys, providing information on beginning salary offers to graduates at all degree levels from a representative group of U.S. colleges and universities. CPC survey results are reported by gender, field, type of employer, and degree level.[4]

Inconsistencies in the Data Bases

The available data sources on engineering differ in scope and purpose as well as methodology. Although each data base responds to the information needs of its data-collection agency, differences in target populations, sampling methods and size, response rates, data elements, etc., produce information that is seldom compatible or consistent. Of concern here are the methodological and definitional differences in BLS and NSF surveys, which are major sources of information on the engineering labor market. Although the BLS and NSF surveys share some common origins, differences in their survey methodologies make comparisons difficult and often produce inconsistent results, such as varying work force estimates.

In calculating engineering manpower counts, BLS relies on the Industry/Occupational Matrix derived from two sources of information: the Occupational Employment Survey (OES), which is a comprehensive, establishment-based mail survey, and the Current Population Survey (CPS), which is a household survey of relatively small sample size. In the OES, the respondent is a representative of the surveyed industry who provides information on the number of persons working as engineers. In the CPS, the interviewee is a member of the household, providing occupational information on himself/herself as well as other members of the household.

In contrast, NSF estimates are based on responses of individual scientists and engineers to three mail surveys: the National Survey of Natural and Social Scientists and Engineers, the Survey of Doctorate Recipients, and the Survey of Science, Social Science, and Engineering Graduates. NSF relies on a complex computer-based algorithm to screen respondents as engineers, using educational credentials, self-reported occupational description, and professional identification.

BLS and NSF engineering work force estimates vary also because of differences in classification systems used to define or code engineers.

There are seven divisions in the OES classification system:

1. Managerial and administrative occupations
2. Professional, paraprofessional, and technical occupations
3. Sales and related occupations
4. Clerical and administrative support occupations
5. Service occupations
6. Agriculture, forestry, fishing, and related occupations
7. Production, construction, operating, maintenance, and material handling occupations.

Respondents filling out information on the number of engineering jobs in their organizations are instructed:

> Include persons engaged in the potential application of physical laws and principles of engineering for the development and utilization of machines, materials, instruments,

[4]There are a number of other national data sources that have not been included here because of their educational focus--for example, Cooperative Institutional Research Program of the University of California, Los Angeles, and the American Council on Education (from which annual freshman norms are derived); and the Graduate Records Examination files of the Educational Testing Service.

processes, and services. Include engineers in research, development, production, technical services, and other positions that require knowledge normally obtained through completion of a 4-year engineering college program. Exclude persons trained in engineering who may be currently working in positions not requiring engineering training.

Engineering is included in the second category--that is, "professionals, paraprofessionals, and technical occupations"--and all engineering-trained personnel working in jobs that are included in the remaining occupational categories are not identified as enginee.

Engineering Classification Systems

Classification systems used by different data-collection agencies vary somewhat. For example, engineering taxonomies used in OES questionnaires are "custom-designed" to the industrial sector covered. For instance, the questionnaire sent to the mining and quarrying industry includes the following:

- Metallurgists and metallurgical, ceramic, and materials engineers
- Mining engineers, including mine safety (mine equipment, design engineers, etc.)
- Civil engineers, including traffic (forest engineers, structural engineers, etc.)
- Mechanical engineers (facilities or products mechanical design engineers, etc.)
- All other engineers (industrial engineers, electrical and electronics engineers, etc.)

The questionnaire to the oil and gas extraction industry, on the other hand, includes the following:

- Mining engineers, including mine safety
- Petroleum engineers (drilling engineers, mud analysis well-logging captains, etc.)
- Chemical engineers (absorption and adsorption engineers, etc.)
- Civil engineers, including traffic (structural engineers, etc.)
- Electrical and electronics engineers (computer engineers, etc.)
- Industrial engineers, except safety
- Safety engineers, except mining (pollution control engineers, fire protection engineers, etc.)
- Mechanical engineers (facilities or products mechanical design engineers, etc.)
- All other engineers (marine engineers, biomedical engineers, etc.)

In the CPS, the Standard Occupational Classification is used to code occupational information given by a respondent regarding his/her own job or that of other members of the household. Engineering codes include the following:

- Aerospace engineers
- Agricultural engineers
- Civil engineers
- Chemical engineers
- Electrical and electronics engineers
- Industrial engineers
- Marine and naval engineers
- Mechanical engineers
- Metallurgical and materials engineers
- Mining engineers
- Nuclear engineers
- Petroleum engineers
- Engineers, n.e.c.

Computer system analysts and scientists are coded separately and reported under the "Mathematical and computer scientists" category, in surveys by NSF. Engineering teachers are coded separately and reported as postsecondary teachers. Sales engineers are coded under sales occupations.

In summary, BLS's definitions are occupation-specific, and "occupation" is defined as the one in which an employee or respondent is working rather than the occupation for which he/she may have been trained. As a result, an employee trained as an engineer but working as a drafter is reported (or coded) as a drafter, and vice versa.

The engineering fields used in the NSF 3-level algorithm are:

- Aeronautical and astronautical engineers
- Chemical engineers
- Civil engineers
- Electrical and electronics engineers
- Industrial engineers
- Materials engineers
- Mechanical engineers
- Mining engineers
- Nuclear engineers
- Petroleum engineers
- Other engineers (including systems engineers, sales engineers, marineengineers or naval architects, environmental or sanitary engineers, agricultural engineers, etc.)

Appendix A-3 presents classification systems used by NSF and NCES. An important topic for the workshop participants is to discuss to what degree these classification and definitional systems can be improved to make them more responsive to emerging fields in engineering education and occupations in the 1990s.

Engineering Manpower Issues and Data Needs for the 1990s

The Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers discussed several engineering manpower questions and decided that the major manpower issues for the 1990s centered around the following topics:

1. Nature and scope of *Occupational Mobility*: flow dynamics; career patterns of engineers with different educational levels and training; fungibility of the engineering work force; resiliency
2. *Technical Currency:* effects of new technologies/fields on U.S. engineers; nature, scope, and effectiveness of continuing education and in-service training
3. *International Flows*: net effects on U.S. engineering work force; number and types of foreign engineers who enter, leave, or remain in the U.S. engineering community
4. *Women and Minorities*: nature and effectiveness of increasing the participation of underrepresented groups; numbers and utilization patterns of women and minorities; tracking whether participation is increasing

In addition to discussing the methodological problems of existing data sources, workshop participants are expected to evaluate existing data sources and determine the following:

- How adequate is the current taxonomy of engineering fields and functions?
- How can the various data bases be used in conjunction with one another? How can classification systems and definitions be standardized? How can the major sources of engineering information be integrated into one data base?
- Can these manpower questions be answered with available data? If not, how can the existing data bases be improved or expanded to provide answers to these questions? What kinds of new data should be collected to answer these questions?

This section briefly discusses the types of information needed to answer each manpower question and the availability of such information from existing data bases.

Nature and Scope of Occupational Mobility

The major issues involve flow dynamics of the engineering labor market, career patterns of engineers with different educational levels and specialization, fungibility, and the resiliency of the engineering work force:

1. What are the typical career patterns of engineers in different fields? with different degrees? What causes deviations from the "average"?
2. How many engineers change employers? Why? What is the longevity of engineering graduates in different positions? How many for how long stay in industry, private practice, or academe?
3. What percentage of engineers work in engineering management, manufacturing, research, and development? What are the rates of upward mobility? What factors contribute to or are associated with such career changes?
4. What are the components of the engineering manpower supply pipeline? Which of these components are the most significant in terms of magnitude, propensity for short-term changes, and long-term changes?
5. Upon graduation, how many engineers accept jobs outside the discipline they majored in? Outside the engineering profession? How many continue their education in other than the engineering profession?
6. What proportion of people with a bachelor's, master's, and Ph.D. in engineering are currently not employed in engineering work or in the management of engineering work? Of the group, what is their current primary activity?
7. How many people holding a job with engineering in the title have degrees in engineering? How many people without a degree in engineering are performing engineering jobs (with or without the title)? What disciplines did they study at the university level for each of the various jobs?
8. How many engineers annually leave their profession to enter the "technical reserve pool"? By age? By discipline? By industry? Why? How many engineers return to the engineering pool from the technical reserve pool? By age? By discipline? By industry?
9. How many engineering technicians are there? What are their demographic and employment characteristics? How many technologists are there? What proportion of the engineering labor market do they represent?
10. What is the geographic mobility of engineers?

Most of these questions require longitudinal data, involving follow-up surveys (of graduates as well as those already employed) and detailed educational and employment information to track career mobility and changes. A likely data source is NSF's Scientific and Technical Personnel Data System. The surveys of recent science and engineering graduates and doctorate recipients provide information on employment plans and opportunities of each new stock of engineer; the data base includes various demographic and educational background questions that can be used as control variables. Further, NSF's experienced sample of scientists and engineers, drawn from the 198[illegible] postcensal survey and followed up in 1984 and 1986, provides a rich source of information to track individual career changes, controlling for numerous demographic and educational variables. Moreover, NSF data can also be used to describe the nature--and, to some degree, the scope--of inflows from science to engineering as well as outflows from engineering to other occupations. Information on inflows into engineering of people with nonscience backgrounds and on upper mobility within the technologist or technician pool can, to some degree, be obtained from BLS data bases.

In general, information is more readily available for recent graduates from any discipline or at any degree level who enter the engineering pool than for persons who transfer into the engineering pool from a different stock (such as nonengineering faculty, technician pool, staff support, or technical reserve).

Technical Currency

Concerns here include the resiliency and fungibility of engineering manpower to respond to changing labor-market conditions and the scope and effectiveness of continuing education and in-service programs to reduce technical obsolescence. The questions include:

1. What are the utilization patterns of engineers in different specialties? How is the utilization of different engineers being affected by new technologies, such as computer-aided design?
2. What are the most important ways to improve resilience (ability to adapt to new circumstances) in the engineering work force?
3. What is the scope, nature, and effectiveness of continuing education and in-service programs?
4. What is the degree of obsolescence throughout the engineering profession? What is being/can be/should be done to minimize it?

Although it may be possible to enumerate changes in the utilization patterns of different types of engineers (for example, by documenting changes in demand for engineering work entailed by a shift in emphasis from the development of space systems to the revitalization of manufacturing facilities), it is more difficult to measure and document resiliency, which may require more qualitative than quantitative data.

The questions regarding the nature, scope, and effectiveness of continuing education and in-service programs require data from academe, industry, and individuals. NSF's data base on experienced scientists and engineers includes questions regarding participation in employer-training facilities, adult education centers, and courses presented by professional associations. Although information is available on the number of engineers who have taken such courses, the available data do not permit conclusions about the amount of resources directed to such courses, the exact nature of the courses, and the impact of such courses on engineering employment.

International Flows

Because of the increasing preponderance of foreigners among engineering students, faculty, and practitioners, the involvement of foreign nationals in U.S. engineering and technology has become an increasingly important issue. The following questions are frequently asked:

1. How many and what types of foreign engineers enter, leave, and remain in the engineering work force? How long do they stay?
2. What are the major countries from which foreign engineers come? What factors promote the flow of foreign engineers to the United States?
3. How many American engineers actually emigrate to foreign countries? How many seek short-term or long-term employment abroad? In what disciplines? What are the major countries to which American engineers go for employment? In what engineering discipline? What are the determinants of American engineers seeking employment abroad?
4. What are the net effects of employment of foreign engineers in the U.S. engineering work force?

The following data sources, many of which remain relatively untapped, can provide information on foreign citizens:

- Annual Census of Foreign Students (Institute of International Education)
- Fall Enrollment and Compliance Report; Degrees and Other Formal Awards Conferred (National Center for Education Statistics, U.S. Department of Education)
- Engineering and Technology Enrollments and Degrees (Engineering Manpower Commission)
- National Survey of Natural and Social Scientists and Engineers (National Science Foundation)
- Survey of Science, Social Science, and Engineering Graduates (National Science Foundation)
- Survey of Earned Doctorates (National Science Foundation)
- Scientists and Engineers Abroad (National Science Foundation), based on data of the Immigration and Naturalization Service, U.S. Department of Justice
- The Decennial Census (Census Bureau, U.S. Department of Commerce)
- Current Population Surveys (Census Bureau, U.S. Department of Commerce)

Women and Minorities

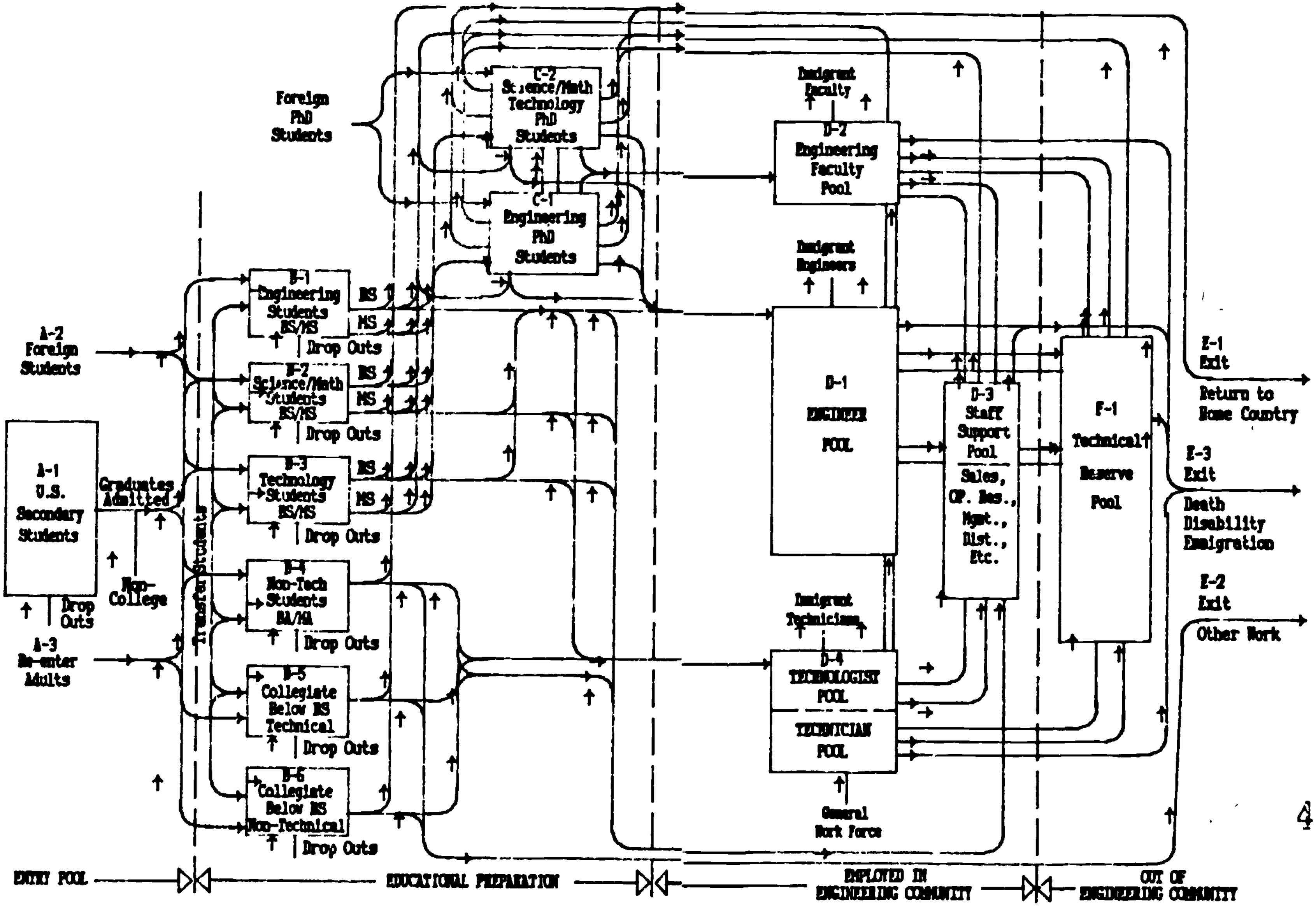
The recent declines in the number of U.S. males interested in the sciences and engineering have intensified interest in increasing participation of women and underrepresented minorities--that is, blacks, Hispanics, and American Indians. Questions raised include the following:

1. What are the numbers and characteristics of women and minorities who enter engineering?
2. What percentage of women and minorities holding engineering baccalaureates pursue graduate education in engineering? What factors influence this decision? What are the structural barriers to their pursuit of graduate education in engineering?
3. What are the utilization patterns of women and minority engineers by field, industry, and type of activity? What factors determine the career patterns of women and minority engineers?
4. How different are the career aspirations of male and female engineers and minority and nonminority engineers? What is the relationship between their career aspirations and career attainment? What factors lead to the lower participation rates of women and minorities in engineering, as compared to the participation rates of men and whites? What are the barriers to the pursuit of engineering careers by women and minorities? What steps can/should be taken to increase women and minority faculty recruitment and retention in engineering?

For descriptive purposes, most of the data bases discussed here include information by sex and by ethnicity--for example, the Doctorate Records File, NSF's Scientific and Technical Personnel Data System, and the Decennial Census. The Current Population Surveys also provide information on the sex of the respondent, although the sample size is too small for detailed analysis. However, most of these data bases can be manipulated to provide any cross-tabulations by sex.

Appendix A-1
Comprehensive Flow Diagram
of the U.S. Engineering Community

40



Committee on the Education and Utilization of the Engineer, National Research Council, *Engineering Infrastructure Diagramming and Modeling,* Washington, D.C.: National Academy Press, 1986, pp. 24-25.

Appendix A-2
Major Engineering Data Bases

Accreditation Board for Engineering and Technology (ABET)

ABET, a federation of 26 engineering societies representing more than 1,300,000 engineers, deals with matters pertaining to education in engineering, engineering technology, and related areas. It sets the policies and standards for accrediting engineering and engineering technology departments in U.S. institutions of higher education and evaluates the programs offered in those departments. It maintains data on all such programs, beginning in 1936, when accreditation in engineering began. The data represent those included in the evaluation of both each recognized institution and each individual program. ABET data are generated each year by those institutions and programs being accredited and then verified during the accreditation process by an evaluating team. In addition, ABET responds to the needs of the engineering profession by conducting periodic studies.

Data Bases	*Respondent*
Engineering Accreditation Commission	Educational institution
Technology Accreditation Commission	Educational institution
Related Accreditation Commission	Educational institution
Quality of Engineering Education	Accreditation commission
Data collection method:	Campus surveys, visits, institutional reports
Frequency:	Annual
Availability:	Reports, tables, graphs
Personal data elements:	None
Education data elements:	Level, field, degree; faculty and student numbers; faculty-student ratio; faculty profiles; equipment; courses offered; cost of education; expenditures
Employment data elements:	Biographical elements; salaries; consultancies

Engineering Manpower Commission (EMC)

The EMC is a major source of engineering educational information. Through mail surveys sent to educational institutions, EMC collects and reports data on engineering and technology enrollments and degrees annually. EMC also conducts annual surveys of engineering compensation and biennial Surveys of Salaries of Engineers in Education. Since 1986 all EMC enrollment and degree surveys are being processed on PC-compatible equipment and are available in machine-readable format.

Engineering and Technology Enrollments Surveys

The annual engineering enrollments survey includes all higher education institutions in the United States and its territories that have at least one engineering curriculum approved by the Accreditation Board of Engineering and Technology (ABET) and all other schools that award degrees in engineering at the bachelor's level or higher. The 1986 survey included 311 institutions, of which 270 were ABET-approved. The technology survey included 257 schools, of which 185 were ABET-approved. Enrollment data are collected for all students and are also broken down for women, blacks, Hispanics, American Indians, Asians/Pacific Islanders, and foreign nationals. Program variables include year-in-school status for full-time undergraduates and type of degree sought (master's, professional engineering, or doctorate) for those in full-time graduate study. Part-time students are tabulated separately at the undergraduate and graduate levels, irrespective of their year in school or of the type of degree sought. Tables are presented separately by school (listed alphabetically by state) and by major discipline (approximately 20 engineering and 20 technology groups).

Engineering and Technology Degrees Granted Survey

The annual degrees survey includes all higher education institutions that award engineering or engineering technology degrees. The 1986 survey included 303 institutions awarding engineering degrees and 282 schools with engineering technology programs. Degree information is reported in three volumes. Part I presents descriptive data by school, in alphabetical order by state, and for each major type of curriculum, including control (public, private) and accreditation status. Cross-tabulations are by degree (bachelor's, master's, professional, and doctorate) in engineering and certificates (associate's, bachelor's, and master's) in engineering technology. Summary tables provide both overall numbers of degrees across all schools and states and those for women, blacks, Hispanics, American Indians, Asian Americans, and foreign nationals. Part II presents detailed information for minorities, and Part III provides tabulations of the degree data by curriculum.

EMC degree information is not completely compatible with NCES degree information. NCES obtains data on all postsecondary programs and places computer science in its own category outside engineering, whether the degrees come from an engineering school or not. EMC reports all enrollment and degrees issued by engineering schools to the extent that these schools choose to report computer science.

Professional Income of Engineers Survey

Annual base-salary information on engineers employed in industry is obtained from approximately 260 industry participants. Forms are sent to all of the engineering employers identified in the Peterson *Guide to Scientific, Engineering and Computer Jobs* plus added employers known to be missing from the Peterson list and others that have participated in prior surveys. Returns are weighted to bring the distribution of engineers in line with the BLS Occupation/Industry Matrix. In 1987 this survey reported on the compensation of over 113,000 engineers.

Data are presented by industry sector, level of highest engineering degree, supervisory-nonsupervisory status, and experience (years since receiving the bachelor's degree in engineering). Thus, the data can be used to measure the relative propensity of different industry sectors to employ people with advanced degrees, as well as to gauge salaries; data also yield distributions of engineers by levels of experience. Tabulations are also provided for differences by size of employer and region. EMC salary data are not presented by types of engineering specialty; however, EMC reports industry averages.

Two reports are issued: the *Special Industry Report* includes all possible details except data on engineers employed by government agencies; *Professional Income of Engineers* is an abridgement, leaving out detailed tabulations by level of earned engineering degrees and adding in the data for engineers in government. EMC has time-series data from these surveys dating back to 1953.

Survey of Salaries of Engineers in Education

EMC also does a similar biennial Survey of Salaries of Engineers in Education. The last one was in 1986; the 1988 version is currently under way. Coverage is good--around three-quarters of all engineering faculty were included in the last one. Data are presented by type of school (Ph.D.-granting, non-Ph.D.-granting, and engineering technology) and by academic rank (full, associate, assistant professors plus instructors, researchers, other nonteaching faculty, and administrators).

Data Bases	*Respondent*
Engineering and Technology Degrees Granted	Educational institution
Engineering and Technology Enrollments	Educational institution
Professional Income of Engineers	Employment institution
Salaries of Engineers in Education	Educational institution

Data collection method:	Mail survey
Size of sample:	Educational surveys: over 300 institutions; PIE: about 260 industries
Frequency:	Annual except SEE is biennial
Availability:	Enrollment and degree surveys: CP machine-readable; salary surveys: tabulations
Personal data elements:	Sex, ethnicity, nationality reported but cannot be cross-tabulated
Education data elements:	Level, type, and field of degree
Employment data elements:	Salary surveys: salary and industry sector

American Society for Engineering Education (ASEE)

ASEE conducts an annual survey of engineering school research and graduate study, as well as annual or biannual surveys of engineering and engineering technology faculty and graduate students, at all engineering schools. The mail surveys are completed by educational institutions; information is reported in *Engineering Education* (a special issue is devoted to the research survey) and is also available for researchers.

The annual research and graduate study questionnaire has been consistent for 20 years, with only minor changes. It covers names of administrators, admission requirements, number of faculty, number of undergraduates, graduate degree requirements, extension centers for off-campus study, faculty and graduate enrollment and degrees granted by department, appointments made to graduate students, research areas of doctoral theses, numbers of personnel engaged in separately budgeted research, research expenditures by source of support, separately budgeted research expenditures, engineering-related research outside the engineering college, and separately funded laboratories.

Questionnaire design of the faculty survey has varied somewhat; for instance, demographic questions are not worded consistently from one survey to the next, as evidenced in the 1985-86 and 1987-88 questionnaires. The 1987-88 survey included faculty shortage information by engineering fields and academic rank for number of authorized and funded positions, positions unfilled since 1987 fall term, and unfilled since 1986 as well as questions relating to recruitment problems. Information was also collected on new appointments to full-time tenure and nontenure tracks by academic rank and departures from full-time faculty. Attitudinal questions relating to "problems in engineering education" were also asked.

The faculty surveys usually provide information about characteristics (e.g., tenured, have doctorate, ethnic minority, women, age, academic rank, and engineering specialty) of U.S. engineering and technology faculty.

Data Bases	*Respondent*
Engineering College Research and Graduate Study	Educational institution
Engineering Faculty and Graduate Students	Educational institution
Data collection method:	Mail survey
Size of sample:	All schools of engineering
Frequency:	Research: annual; Faculty: annual or biennial
Availability:	*Engineering Education*; tabulations
Personal data elements:	Faculty survey: national origin of graduate students
Education data elements:	Level; field; type of degree; number of students, degrees granted, by department; appointments made to graduate students; research areas; number of personnel in separately budgeted research; research expenditures by source of support; separately budgeted research expenditures
Employment data elements:	Number of faculty; faculty positions authorized; faculty mobility; recruitment of faculty

National Society of Professional Engineers (NSPE)

NSPE conducts annual salary surveys of its membership, which includes individuals without professional engineering degrees. Detailed information is collected on employment (e.g., type of employer, length of experience, industry or service employer, type of supervisory responsibility, size of organization, number of engineers employed, geographic area, salary), ethnic background of respondents, and highest degree earned. The data are only available in tabular form. In addition, because the survey population is limited to NSPE membership, the data are of limited use. NSPE members differ from engineers in general: they tend to be older and more experienced. Therefore, the survey results are not readily generalizable to the total engineering population, even if age differences are controlled for.

Data Base	*Respondent*
Professional Engineer Income and Salary Survey	Individual members
Data collection method:	Mail survey
Size of sample:	Approximately 63,000 (excludes students and retired persons)
Frequency:	Annual
Availability:	Tabulations
Personal data elements:	Ethnicity
Education data elements:	Level, engineering discipline(s)
Employment data elements:	Current occupation, type of employer, work activities, level of professional responsibility, years of experience, salary, geographic region, metropolitan area

National Science Foundation (NSF)

NSF's Division of Science Resources Studies designs, conducts, and supports surveys collecting information on scientific and engineering personnel, funding, and inputs/outputs to the science and technology enterprise. The definitions used in estimating the numbers of engineers are based on educational credentials (at least 2 years of college), self-reported occupations (is or has been employed in an engineering occupation), and/or professional identification as an engineer on the basis of total education and work experience. NSF collects data on computer specialists separately from data collected on engineers.

NSF maintains the Scientific and Technical Personnel Data System, which comprises three surveys and a computer-based model: the National Survey of Natural and Social Scientists and Engineers (NSNSSE); the Survey of Doctorate Recipients; and the Survey of Science, Social Science, and Engineering Graduates (SSSSEG). While each survey provides information on a select portion of the total S/E population, the model--the Science and Engineering Tabulating Model--combines the results of the NSNSSE with that of the SSSSEG to produce national estimates of the total stock of engineers and scientists in the United States.

National Survey of Natural and Social Scientists and Engineers

Starting with the 1970 Census of Population, this survey provides data on the number and characteristics of individuals who were identified among the science and engineering population. The initial survey in this series, based on the 1980 Census of Population, was conducted in 1982 for NSF by the *Bureau of the Census*. Since then, follow-up surveys have been conducted in 1984 and 1986, providing a longitudinal profile of scientists and engineers. This extremely valuable source of information provides descriptive and analytic data, including education and training (e.g., level and field of degree), demographic characteristics (e.g., sex, age, race, Hispanic origin, handicapped status, marital status), citizenship, employment status (e.g., full/part-time, reasons for non-S/E employment), and detailed employment profile (e.g., occupation, type of employer, primary work activity, salary, work experience). The questionnaire also provides information on continuing education, in-service training, and other related program participation.

Survey of Science, Social Science, and Engineering Graduates

The objective of this biennial survey, conducted for NSF by the *Institute for Survey Research, Temple University*, is to provide data on the demographic (e.g., sex, race, Hispanic heritage, citizenship, marital status, and age), education (e.g., date and year of degrees, major field of degrees), and employment [e.g., early career experiences, labor force status, sector of employment, primary work activity, salary, and reasons for employment in a non-S/E job (if applicable)] characteristics of individuals who received bachelor's or master's degrees in science and engineering fields from U.S. institutions. The most recently completed survey was conducted in 1986, covering the graduating classes of 1982, 1984 and 1985.

Survey of Doctorate Recipients

Conducted biennially by the *National Research Council* for NSF, this survey provides national estimates of the population of science and engineering doctorates. The survey is based on a sample of individuals drawn from the Doctorate Records File (see "Survey of Earned Doctorates" below) and includes individuals who received doctorates during the preceding 42-year period in the natural and social sciences, mathematics, and engineering from U.S. institutions, as well as individuals who received research doctorates in non-S/E fields but were known to be employed as scientists and engineers. Data are collected on major demographic characteristics (e.g., age, citizenship, marital status, sex, race, and Hispanic heritage) and employment (e.g., employment status, sector of employment, primary work activity, salary, and, if applicable, reasons for working in a non-S/E job). The most recent survey was conducted in 1987.

Other NSF Surveys and Data Bases

Survey of Graduate Science and Engineering Students and Postdoctorates

This is the only national survey that collects information on the characteristics of graduate science and engineering enrollment at the departmental level. It is conducted by ***Quantum Research Inc.*** for NSF. The survey population includes both doctorate- and master's-granting institutions, as well as medical schools and other specialized institutions offering first-professional doctorates in health-related fields. It provides information on the head counts of full-time graduate students, with information on sources and mechanisms of their major support, sex, race, ethnic background, level of study, and citizenship. For graduate students enrolled part-time, summary data on sex and racial/ethnic background are available. Summary information on postdoctorates and nonfaculty research staff also cover source and mechanisms of support, sex, and citizenship.

Survey of Earned Doctorates

This survey, conducted for NSF by the *National Research Council*, collects information annually on the number and characteristics of recipients of doctorates awarded by U.S. institutions. The survey questionnaire is distributed, with the cooperation of deans of graduate schools, to all new recipients of Ph.D.s or the equivalent (e.g., E.D.) and requests information in three major categories: socioeconomic characteristics (e.g., date and place of birth, sex, marital status, number of dependents, citizenship, race, Hispanic heritage, presence of physical handicap, and educational attainment of parents), education (e.g., state and year of high school graduation, dates and names of colleges attended, fields of study and degrees, title of dissertation and field, and kind and sources of financial support during graduate study), and postgraduation plans (e.g., plans for further education or employment, including the type of employer, work activity, field, and organization).

Survey results are used to construct the Doctorate Records File maintained by the National Research Council. This virtually complete listing of the over 818,000 recipients of doctorates awarded by U.S. universities since 1920 includes research doctorates in all fields, but excludes professional (clinical) degrees such as the M.D. or the D.V.M.

Finally, NSF reports data from the U.S. Immigration and Naturalization Service on the annual inflows of foreign scientists and engineers.

Data Bases	*Respondent*
National Survey of Natural and Social Scientists and Engineers (NSNSSE)	Individual
Survey of Science, Social Science, and Engineering Graduates (SSSSEG)	Individual
Survey of Earned Doctorates (SED)	Individual
Survey of Doctorate Recipients (SDR)	Individual
Survey of Graduate Science and Engineering Students and Postdoctorates (SGSESP)	Departments

Data collection method:	Mail survey
Size of sample:	
NSNSSE	138,000 (1982 survey)
SSSSEG	35,900 (1986 survey)
SDR	60,000 (1987 survey)
SGSESP	619 departments (1986 survey)
Frequency:	Biennial, except SED and SGSESP are annual

Availability:	Computer tapes (except SDR and SED); detailed tabulations
Personal data elements:	Age, sex, race, marital status, citizenship
Education data elements:	Level, field, type of degree, sources of support
Employment data elements:	Employment status, current occupation and type of employer, work activities, salary

National Center for Education Statistics (NCES)
U.S. Department of Education

The NCES has been a major source of trend data on enrollments and degrees in U.S. postsecondary education since 1966. Information is completed by all educational institutions. Fall Enrollment and Compliance Report of Institutions of Higher Education provides information on enrollments by control of institutions (public, private), level of degrees granted, and disciplinary specialty, sex, race, and age of students (some information is not collected annually). Degrees and Other Awards Conferred provides similar information on types of degrees conferred by higher education institutions and fields of study. Data are available on computer tapes.

NCES has begun to expand both its study population (from approximately 3,400 higher education institutions to over 13,000 postsecondary institutions) and the scope of its surveys. NCES recently began to conduct two new surveys, one on faculty and one on student finance. The National Survey of Postsecondary Faculty will be available in fall 1988, after data are collected this spring. This survey will be repeated every 3 years. Data from the National Postsecondary Student Aid Study, covering students enrolled in the fall of 1986, will be available in 1988. This survey will also be repeated every 3 years. In addition, the Postsecondary Longitudinal Study will involve a sample of first-time students across different types of institutions, to be followed for 6 years, will be initiated in 1990, and will be repeated every 3 years. The Recent College Graduates Survey will also track students for 6 years, beginning in their senior year of college. This study will be initiated in 1990, and a new cohort will be added every 3 years.

Data Bases	*Respondent*
Fall Enrollment and Compliance Report	Educational institution
Degrees and Other Formal Awards Conferred	Educational institution
Data collection method:	Mail survey
Size of sample:	Over 3,400 higher education institutions, now expanded to over 13,000 postsecondary institutions
Frequency:	Annual
Availability:	Computer tapes
Personal data elements:	Fall Enrollment: Sex, race (biennially), age (every 4 years); Degrees Conferred: sex, race (biennially)
Education data elements:	Fall Enrollment: Level, major program area, institution, control of institution (private/public); Degrees Conferred: level, field of study
Employment data elements:	None

Bureau of the Census
U.S. Department of Commerce

Decennial Census

The Decennial Census, a mail survey of households, provides both the basic sampling frame from which NSF's postcensal surveys of scientists and engineers are drawn and much-needed, though largely untapped, information on foreign nationals. The Bureau of Census' 1980 occupational codes for engineers include agricultural, aerospace, chemical, civil, electrical/electronics, industrial, marine/naval, mechanical, metallurgical/materials, mining, nuclear, petroleum, and others. Separate codes are provided for engineering faculty, those employed in managerial positions, and engineers employed in nonengineering occupations. Computer scientists and analysts are coded separately. Codes are also provided for engineering and related technologists and technicians in electrical/electronics, industrial, mechanical, and other engineering.

Data Base Decennial Census	*Respondent* Household
Data collection method:	Initial mail survey; personal interview follow-up with nonrespondents to mail survey
Frequency:	Every 10 years
Availability:	Special computer tapes
Personal data elements:	Age, sex, race, marital status, citizenship, income
Education data elements:	Level and field
Employment data elements:	Employment status; occupation, type of employer, industry, work activities, and salary of current job

Bureau of Labor Statistics (BLS)

BLS conducts the Occupational Employment Survey and integrates results with data on self-employed engineers from the Current Population Surveys to construct the Industry/Occupational Matrix, used in estimating base-year numbers of engineers and in making employment projections. BLS counts of engineers differ from those of NSF, due to differences in survey methodologies and definitions. First of all, BLS surveys employers, not the engineers themselves. In addition, BLS excludes military personnel, managers, and engineering faculty in its estimates. Its counts are based on occupational classifications and self-identifications, not on educational credentials: engineering-educated personnel employed in nonengineering jobs are usually excluded.

Occupational Employment Survey (OES)

The OES is a cooperative, federal-state, data-collection program administered through state employment-security agencies in the 50 states and the District of Columbia; a 3-year survey cycle is needed to cover the entire industrial sector. This mail survey collects information on employment in over 650 occupations that are based on two classification systems: the Dictionary of Occupational Titles (DOT) and the Standard Occupational Classification System (SOC). Included among these occupations are 60 science, engineering, and related S/E support technician occupations. The survey provides position counts by industry. "Engineers" are defined as

> persons engaged in the practical application of physical laws and principles of engineering for the development and utilization of machines, materials, instruments, processes, and services, including those engaged in research, development, production, technical services, and other positions which require knowledge normally obtained through completion of a 4-year engineering college program.

Employment data are collected on the number of persons working as engineers. Therefore, persons trained in engineering but currently working in other occupations are not identified as engineers. Sales engineers and college engineering teachers can be identified, although they are not included with counts of engineers.

Current Population Survey (CPS)

The CPS, based on monthly household structured interviews, is designed to provide employment and demographic statistics. The survey results are used by BLS to estimate numbers of employed engineers. The survey questionnaire includes detailed employment and labor-market participation questions as well as limited information on demographic (e.g., age, sex, race) and educational variables. Sometimes information on citizenship is also provided. Starting in 1983, the occupational taxonomy in the CPS is the same as that in the 1980 Decennial Census. However, the sample size is not sufficient to provide detailed estimates for industry and education.

Data Bases	*Respondent*	*Data Collection Method*
Occupational Employment Survey (OES)	Employment institution	Mail survey
Current Population Survey (CPS)	Household	Structured interview
Size of sample:		
OES	160,000	
	240,000	
CPS	322,000	
	68,500	

Frequency:	OES: periodic 3-year cycle for different groups of industries; CPS: monthly
Availability:	Special tapes; limited tabulations
Personal data elements:	OES: none; CPS: age, sex, race, marital status, income
Education data elements:	OES: none; CPS: level
Employment data elements:	Occupation, type of employer, and industry of current job; CPS also provides employment status and current salary

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Battelle

Data Base National Survey of Compensation	*Respondent* Employment establishment
Data collection method:	Mail survey
Size of Sample:	1,254 R&D centers
Frequency:	Annual
Availability:	Tabulations
Personal data elements:	None
Education data elements:	Level and field
Employment data elements:	Occupation, type of employer, industry, level, work activities, years since bachelor's degree, and salary of current job

College Placement Council

Data Base College Placement Council Salary Survey	*Respondent* College placement offices collect information from individuals and employers
Data collection method:	Mail survey
Size of sample:	186 placement officers in 1988
Frequency:	4 times per year (January, March, July, September)
Availability:	Quarterly report, CPC Salary Survey
Personal data elements:	Sex
Education data elements:	Level and curriculum
Employment data elements:	Type of job function, industry sector, average starting salary offers made to college graduates

Appendix A-3
Engineering Taxonomies

1986 National Survey of Natural and Social Scientists and Engineers
Major Fields of Study

Code	Description
	Biological and Agricultural Sciences and Related Fields
101	Agriculture, business
102	Agriculture, general
103	Agronomy, field crops
104	Anatomy, histology
105	Animal physiology
106	Animal science
107	Bacteriology, virology, mycology, parasitology
108	Biochemistry
109	Biology, general
110	Biometrics and biostatistics
111	Biophysics
112	Botany, general
113	Cell biology
114	Dairy sciences (dairy husbandry)
115	Ecology
116	Embryology
117	Entomology
118	Farm management
119	Fish and game or wildlife management
120	Food science (food technology and processing, dairy manufacturing and technology, food industry)
121	Forestry
122	Genetics
123	Horticulture
124	Immunology
125	Marine biology
126	Microbiology
127	Molecular biology
128	Natural resources management
129	Neurosciences
130	Nutrition
131	Pathology, human and animal
132	Pathology, plant
133	Physiology, human and animal
134	Physiology, plant
135	Poultry sciences
136	Radiology
137	Soil sciences (soil management, soil conservation)
138	Toxicology
139	Zoology, general
140	Biological and agricultural sciences, other fields
	Education
141	Biological sciences education
142	Guidance and counseling
143	Mathematics education
144	Physical sciences education
145	Social sciences education
146	Education, other fields
	Engineering
147	Aerospace, aeronautical, astronautical and related fields
148	Agricultural
149	Architectural
150	Bioengineering and biomedical engineering
151	Chemical, petroleum refining
	Engineering (Continued)
152	Civil, construction, transportation
153	Computer
154	Electrical, electronics, communications
155	Engineering sciences, mechanics, physics
156	Engineering technology
157	Environmental, sanitary engineering
158	General or unspecified
159	Geological engineering
160	Geophysical engineering
161	Industrial
162	Mechanical
163	Metallurgical, materials, ceramics
164	Mining, mineral, geological
165	Naval architecture and marine engineering
166	Nuclear
167	Ocean engineering
168	Petroleum
169	Textile engineering
170	Engineering, other fields
	Health Fields
171	Medicine or premedicine, and clinical medical sciences
172	Nursing (4 years or longer program)
173	Pathology
174	Pharmacology
175	Pharmacy
176	Health professions, other fields (4 years or longer)
	Mathematical Sciences
177	Actuarial sciences
178	Applied mathematics
179	Computer science
180	Mathematics
	Operations research/management sciences
182	Statistics
	Physical Sciences
183	Analytical chemistry
184	Astronomy
185	Astrophysics
186	Atmospheric sciences and meteorology
187	Atomic—molecular physics
188	Biochemistry
189	Chemistry, general
189	Earth sciences, general
190	Elementary particles and fields
191	Geology
192	Geochemistry
193	Geophysics and seismology
194	Inorganic chemistry
195	Metallurgy
196	Nuclear physics
	Physical Sciences (Continued)
197	Oceanography
198	Organic chemistry
199	Paleontology
200	Pharmaceutical chemistry
201	Physical chemistry
202	Physical sciences, general
203	Physics, general
204	Solid state physics
205	Other, earth sciences
206	Other, physical sciences
	Psychology
207	Clinical
208	Counseling
209	Developmental
210	Educational
211	Experimental
212	Industrial/organizational
213	Physiological
214	Psychology, general
215	Psychometrics
216	Social
217	Psychology, other fields
	Social Sciences
218	Anthropology
219	Criminology
220	Economics, agricultural
221	Economics, except agricultural
222	Geography
223	Political science and government
224	Sociology
225	Social sciences, other fields
	Arts, Humanities, and Other Specialties
226	Architecture
227	Area studies
228	Arts, general
229	Business and commerce, including accounting, hotel and restaurant administration, and secretarial studies
230	English and journalism
231	Fine and applied arts, all fields
232	Foreign language and literature, all fields
233	History
234	Home economics, all fields
235	Law or prelaw
236	Library science
237	Military science, including merchant marine deck officer
238	Philosophy, all fields
239	Religion and theology, all fields
240	Social work
241	Other *(Describe briefly in the applicable item on questionnaire.)*

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1986 National Survey of Natural and Social Scientists and Engineers
Occupations

Code	Description

Engineers, including college professors and instructors

701 Engineer, aeronautical, aerospace, or astronautical
702 Engineer, agricultural
703 Engineer, chemical
704 Engineer, civil or architectural
705 Engineer, computer
706 Engineer, electrical or electronic
707 Engineer, environmental or sanitary
708 Engineer, industrial
709 Engineer, marine engineer or naval architect
710 Engineer, mechanical
711 Engineer, metallurgical or materials
712 Engineer, mining or geological
713 Engineer, nuclear
714 Engineer, petroleum
715 Engineer, sales
716 Engineer, systems
717 Engineer, other fields *(Describe briefly in the applicable item on questionnaire.)*

Computer Specialists, including college professors and instructors

718 Computer programmer
719 Computer scientist
720 Computer systems analyst
721 Other computer specialists *(Describe briefly in the applicable item on questionnaire.)*

Mathematicians, Statisticians and other Mathematical Scientists, including college professors and instructors

722 Actuary, including actuarial mathematician
723 Mathematician
724 Operations research analyst
725 Statistician
726 Systems analyst, except computer systems or data processing (see code 720)
727 Other mathematical scientists *(Describe briefly in the applicable item on questionnaire.)*

Physical Scientists, including college professors and instructors

728 Atmospheric scientist, meteorologist, space scientist
729 Chemist, except biochemist
730 Earth scientist, including geologist, geophysicist, geodesist, etc.
731 Oceanographer
732 Physicist, astronomer
733 Other physical scientists, e.g., geographer, environmental scientist, materials scientist, etc. *(Describe briefly in the applicable item on questionnaire.)*

Biological Scientists, including college professors and instructors

734 Agricultural scientist, food scientist, fishery biologist
735 Biochemist
736 Biological scientist, life scientist, botanist, ecologist
737 Biophysicist
738 Forestry or conservation scientist, including foresters and conservationists
739 Medical scientist, excluding persons who are primarily medical practitioners (see Health Occupations)
740 Other biological scientists *(Describe briefly in the applicable item on questionnaire.)*

Social Scientists, including college professors and instructors

741 Anthropologist
742 Economist, including market research analysts
743 Psychologist
744 Sociologist
745 Other social scientists, e.g., demographer, political scientist, etc. *(Describe briefly in the applicable item on questionnaire.)*

Health Occupations, including persons who are primarily practitioners. Persons engaged primarily in medical research, teaching, and similar activities use code 739, Medical scientist.

746 Dental hygienist
747 Medical technician
748 Physician or surgeon
749 Other health occupations, e.g., dentist, pharmacist, practical and registered nurse, etc. *(Describe briefly in the applicable item on questionnaire.)*

Technicians and technologists, except medical and health

750 Designer, electronic parts
751 Designer, industrial
752 Designer, machine tools
753 Designer, other
754 Drafting occupations, including draftsman
755 Technician, architectural
756 Technician, biological and agricultural
757 Technician, construction and highway
758 Technician, electrical and electronic
759 Technician, industrial engineering
760 Technician, mechanical engineering
761 Technician, other engineering
762 Technician, surveying and mapping (Surveyors, see code 791)
763 Technician, other science
764 Technician, other fields *(Describe briefly in the applicable item on questionnaire.)*

Teachers

765 Teacher, elementary school
766 Teacher, secondary school
767 Teacher, college and university teacher of non-engineering and non-science subjects (Engineering and science teachers, see codes 701–745.)

Administrators, Managers, and Officials, excluding farm

768 Administrator or manager, production and operations
769 Administrator or manager, scientific and technical research and development
770 Administrator, manager, or official, all others, excluding self-employed
771 College president or dean
772 Self-employed proprietor
773 Urban and regional planners

All other occupations

774 Accountant, except financial analyst
775 Administrative support occupations including clerical work (such as bookkeeper, secretary, etc.)
776 Architect
777 Clergy
778 Farmer (owner, manager, tenant or farm laborer)
779 Financial analyst
780 Firefighter or police
781 Historian
782 Laborer, except farm
783 Lawyer or judge
784 Librarian
785 Merchant or shopkeeper, self-employed
786 Operator or fabricator (such as assembler, welder, truck driver, etc.)
787 Postal worker
788 Precision production, craft, and repair occupations (such as carpenter, electrician, mechanic, repair worker, etc.)
789 Sales occupations, excluding sales engineer
790 Social worker
791 Surveyor
792 Other occupations, not specified above *(Describe briefly in the applicable item on questionnaire.)*

1986 Survey of Science, Social Science, and Engineering Graduates
Degree and Employment Specialty List

Agriculture

003 Agricultural economics
004 Agriculture, business
013 Agronomy
014 Animal, dairy, poultry, sciences
015 Farm and range management
016 Fish, game and wildlife management
017 Food sciences
018 Forestry and related sciences
019 Horticulture
020 Natural resources management
021 Soil science
[illegible] Agricultural sciences, other

Biological Sciences

211 Anatomy, histology
213 Biochemistry
714 Biometrics and biostatistics
214 Biophysics
215 Botany
221 Cell and molecular biology
216 Entomology
226 Embryology
217 Genetics
218 Immunology
219 Marine biology
220 Microbiology, bacteriology
227 Neurosciences
222 [illegible]
228 Parasitology
223 Pathology, human, animal, plant
226 Physiology, human, animal, plant
229 Radiology
230 Toxicology
225 Zoology
290 Biological sciences, other

Education

413 Biological sciences education
414 Engineering education
417 Mathematics education
421 Physical sciences education
425 Social science education
490 Education, other

Engineering

511 Aerospace, aeronautical, astronautical
512 Agricultural
513 Architectural
514 Bioengineering and biomedical engineering
515 Chemical, including petroleum refining
516 Civil, construction, and transportation
723 Computer
517 Electrical, electronic, and communication
529 Engineering science, mechanics, physics
519 Environmental and sanitary
520 Geological
521 Industrial
530 Materials
522 Mechanical
523 Metallurgical
526 Mining and mineral
525 Naval architecture and marine
526 Nuclear
531 Ocean
527 Petroleum
528 Textile
751 Operations research/management sciences
590 Engineering, other

Mathematical Sciences

711 Actuarial science
712 Applied mathematics
723 Computer sciences
750 Mathematics
751 Operations research/management sciences
713 Statistics
716 Biometrics and biostatistics
723 Computer and information sciences
780 Mathematics, other

Physical Sciences

720 Astronomy
721 Atmospheric sciences and meteorology
213 Biochemistry
722 Chemistry
761 Earth sciences and geology
733 Metallurgy
742 Oceanography
731 Physics
790 Physical sciences, other

Social Sciences

811 Anthropology
812 Criminology
813 Economics (except agricultural)
816 Geography
118 Linguistics
817 Political science and government
818 Psychology (except clinical)
821 Sociology
822 Urban studies
890 Other social sciences

Health Sciences

611 Clinical psychology
612 Dentistry
614 Hospital and health care administration
615 Medicine or pre-medicine
616 Nursing
617 Pharmacology
618 Pharmacy
690 Other health areas

Arts, Humanities and Other Specialties

910 Area and ethnic studies
911 Architecture and environmental design
110 Arts and letters, general
310 Business and commerce
115 English and journalism
114 Fine and applied arts
116 Foreign language and literature, all fields
815 History
912 Home economics, all fields
913 Law and prelaw
914 Library science
915 Military science, including merchant marine deck officer
814 Philosophy
819 Religion and theology
820 Social work
999 Other specialties

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Survey of Earned Doctorates (1985-86)
Specialties List

AGRICULTURE

000 Agricultural Economics

005 Animal Breeding & Genetics
010 Animal Nutrition
019 Animal Sciences, Other*

020 Agronomy
025 Plant Breeding & Genetics
030 Plant Path. (See also 120)
039 Plant Sciences, Other*

040 Food Sciences
045 Soil Sciences
050 Horticulture Science
055 Fisheries Science
060 Wildlife Management
065 Forestry Science

098 Agriculture, General
099 Agriculture, Other*

BIOLOGICAL SCIENCES

100 Biochemistry
105 Biophysics

110 Bacteriology
115 Plant Genetics
120 Plant Path. (See also 030)
125 Plant Physiology
129 Botany, Other*

130 Anatomy
133 Biometrics & Biostatistics
136 Cell Biology
139 Ecology
142 Embryology
145 Endocrinology
148 Entomology
151 Immunology
154 Molecular Biology
157 Microbiology
160 Neurosciences
163 Nutritional Sciences
166 Parasitology
169 Toxicology
170 Genetics, Human & Animal
175 Pathology, Human & Animal
180 Pharmacology, Human & Animal
185 Physiology, Human & Animal
189 Zoology, Other*

198 Biological Sciences, General
199 Biological Sciences, Other*

HEALTH SCIENCES

200 Audiology & Speech Pathology
210 Environmental Health
215 Public Health
220 Epidemiology
230 Nursing
240 Pharmacy
250 Veterinary Medicine
298 Health Sciences, General
299 Health Sciences, Other*

ENGINEERING

300 Aerospace, Aeronautical & Astronautical
303 Agricultural
306 Bioengineering & Biomedical
309 Ceramic
312 Chemical
315 Civil
318 Communications
321 Computer
324 Electrical, Electronics
327 Engineering Mechanics
330 Engineering Physics
333 Engineering Science
336 Environmental Health Engin.
339 Industrial
342 Materials Science
345 Mechanical
348 Metallurgical
351 Mining & Mineral
354 Naval Arch. & Marine Engin.
357 Nuclear
360 Ocean
363 Operations Research (See also 465, 930)
366 Petroleum
369 Polymer
372 Systems
398 Engineering, General
399 Engineering, Other*

COMPUTER AND INFORMATION SCIENCES

400 Computer Sciences*
410 Information Sci. & Systems*

MATHEMATICS

420 Applied Mathematics
425 Algebra
430 Analysis & Functional Anal.
435 Geometry
440 Logic (See also 785)
445 Number Theory
450 Probability & Math. Statistics (See also 690)
455 Topology
460 Computing Theory & Practice
465 Operations Research (See also 363, 930)
498 Mathematics, General
499 Mathematics, Other*

PHYSICAL SCIENCES

Astronomy

500 Astronomy
505 Astrophysics

Atmospheric & Meteorological Sciences

510 Atmospheric Physics & Chem
512 Atmospheric Dynamics
514 Meteorology
518 Atmos. & Meteorol. Sci., Gen.
519 Atmos. & Meteorol. Sci., Other*

Chemistry

520 Analytical
522 Inorganic
524 Nuclear
526 Organic
528 Pharmaceutical
530 Physical
532 Polymer
534 Theoretical
538 Chemistry, General
539 Chemistry, Other*

Geological Sciences

540 Geology
542 Geochemistry
544 Geophysics & Seismology
546 Paleontology
548 Mineralogy, Petrology
550 Stratigraphy, Sedimentation
552 Geomorphology & Glacial Geology
554 Applied Geology
558 Geological Sciences, General
559 Geological Sciences, Other*

Physics

560 Acoustics
561 Atomic & Molecular
562 Electron
564 Elementary Particle
566 Fluids
568 Nuclear
569 Optics
570 Plasma
572 Polymer
574 Solid State
578 Physics, General
579 Physics, Other*

Other Physical Sciences

580 Environmental Sciences
585 Hydrology & Water Resources
590 Oceanography
595 Marine Sciences
599 Physical Sciences, Other*

PSYCHOLOGY

600 Clinical
603 Cognitive
606 Comparative
609 Counseling
612 Developmental
615 Experimental
618 Educational (See also 822)
621 Industrial & Organizational (See also 935)
624 Personality
627 Physiological
630 Psychometrics
633 Quantitative
636 School (See also 825)
639 Social
648 Psychology, General
649 Psychology, Other*

SOCIAL SCIENCES

650 Anthropology
652 Area Studies
658 Criminology
662 Demography
666 Economics
668 Econometrics
670 Geography
674 International Relations
678 Political Sci. & Government
682 Public Policy Studies
686 Sociology
690 Statistics (See also 450)
694 Urban Studies
698 Social Sciences, General
699 Social Sciences, Other*

HUMANITIES

History

700 History, American
705 History, European
710 History of Science
718 History, General
719 History, Other*

Letters

720 Classics
723 Comparative Literature
729 Linguistics
732 Literature, American
733 Literature, English
734 English Language
736 Speech & Debate
738 Letters, General
739 Letters, Other*

Foreign Languages and Literature

740 French
743 German
746 Italian
749 Spanish
752 Russian
755 Slavic (other than Russian)
758 Chinese
762 Japanese
765 Hebrew
768 Arabic
769 Other Languages*

Other Humanities

770 American Studies
773 Archeology
776 Art History & Criticism
780 Music
785 Philosophy (See also 440)
790 Religion (See also 984)
795 Theatre
798 Humanities, General
799 Humanities, Other*

EDUCATION

800 Curriculum & Instruction
805 Educ. Admin. & Superv.
810 Educational Media
815 Educ. Stat. & Research
820 Educ. Testing, Eval. & Meas.
822 Educational Psychology (See also 618)
825 School Psych. (See also 636)
830 Social Foundations
835 Special Education
840 Student Counseling & Personnel Services
845 Higher Education

Teacher Education

850 Pre-elementary
852 Elementary
854 Junior High
856 Secondary
858 Adult & Continuing

Teaching Fields

860 Agricultural Educ.
861 Art Educ.
862 Business Educ.
864 English Educ.
866 Foreign Languages Educ.
868 Health Educ.
870 Home Economics Educ.
872 Industrial Arts Educ.
874 Mathematics Educ.
876 Music Educ.
878 Nursing Educ.
880 Physical Educ.
882 Reading Edu
884 Science Educ.
885 Social Science Educ.
886 Speech Educ.
888 Trade & Industrial Educ.
889 Teacher & Educ. Specific Subject Areas, Other*

898 Education, General
899 Education, Other*

PROFESSIONAL FIELDS

Business & Management

900 Accounting
905 Banking & Finance
910 Business Admin. & Management
915 Business Economics
920 Marketing Mngmnt. & Research
925 Business Statistics
930 Operations Research (See also 363, 465)
935 Organiz. Beh. (See also 621)
938 Business & Mngmnt., General
939 Business & Mngmnt., Other*

Communications

940 Communications Research
945 Journalism
950 Radio & Television
958 Communications, General
959 Communications, Other*

Other Professional Fields

960 Archltec. & Environ. Design
964 Home Economics
968 Law
972 Library & Archival Science
976 Public Administration
980 Social Work
984 Theology (See also 790)
988 Professional Fields, General
989 Professional Fields, Other*

999 OTHER FIELDS*

1985 Survey of Doctorate Recipients
Employment Specialties List

MATHEMATICAL SCIENCES

000 - Algebra
010 - Analysis & Functional Analysis
020 - Geometry
030 - Logic (see also 834)
040 - Number Theory
050 - Probability
055 - Math. Statistics (see also 544, 670, 725, 727)
060 - Topology
070 - Operations Research (see also 478)
080 - Applied Mathematics
085 - Combinatorics & Finite Mathematics
098 - Mathematics, General
099 - Mathematics, Other*

COMPUTER AND INFORMATION SCIENCES

071 - Theory
072 - Software Systems
073 - Hardware Systems
074 - Intelligent Systems
079 - Computer Sciences, Other* (see also 437, 475)
081 - Information Sci. & Systems*

PHYSICS & ASTRONOMY

101 - Astronomy
102 - Astrophysics
110 - Atomic & Molecular
120 - Electromagnetism
132 - Acoustics
134 - Fluids
135 - Plasma
136 - Optics
140 - Elementary Particles
150 - Nuclear Structure
157 - Polymer
160 - Solid State
198 - Physics, General
199 - Physics, Other*

CHEMISTRY

200 - Analytical
210 - Inorganic
215 - Synthetic Inorganic & Organometallic
220 - Organic
225 - Synthetic Organic & Natural Products
230 - Nuclear
240 - Physical
250 - Theoretical
255 - Structural
260 - Agricultural & Food
270 - Pharmaceutical
275 - Polymer
280 - Biochemistry (see also 540)
298 - Chemistry, General
299 - Chemistry, Other*

EARTH, ENVIRONMENTAL, AND MARINE SCIENCES

301 - Mineralogy, Petrology
305 - Geochemistry
310 - Stratigraphy, Sedimentation
320 - Paleontology
330 - Structural Geology
341 - Geophysics (Solid Earth)
350 - Geomorph. & Glacial Geology
351 - Applied Geol., Geol. Engr. & Econ. Geol.
398 - Earth Sciences, General
399 - Earth Sciences, Other*
381 - Atmospheric Physics & Chemistry
382 - Atmospheric Dynamics
383 - Atmos. & Meteorol. Sci., Other*
388 - Environmental Sciences, General (see also 480, 528)
389 - Environmental Sciences, Other*
390 - Hydrology & Water Resources
370 - Oceanography
397 - Marine Sciences, Other*

ENGINEERING

400 - Aerospace, Aeronautical & Astronautical
410 - Agricultural
415 - Bioengineering & Biomedical
420 - Civil
430 - Chemical
435 - Ceramic
436 - Communications
437 - Computer
440 - Electrical
445 - Electronics
450 - Industrial & Manufacturing
455 - Nuclear
460 - Engineering Mechanics
465 - Engineering Physics
470 - Mechanical
475 - Metallurgical & Phys. Met. Engr.
475 - Systems Design & Systems Science (see also 072, 073, 074)
478 - Operations Research (see also 070)
479 - Fuel Technology & Petroleum
480 - Sanitary & Environmental Health
485 - Naval Arch. & Marine Engr.
486 - Mining & Mineral
487 - Ocean
490 - Polymer
497 - Materials Science & Engineering
498 - Engineering, General
499 - Engineering, Other*

AGRICULTURAL SCIENCES

501 - Agricultural Economics
505 - Animal Breeding & Genetics
509 - Animal Nutrition
512 - Animal Sciences, Other*
500 - Agronomy
511 - Plant Path. (see also 553)
513 - Plant Breeding & Genetics
514 - Plant Sciences, Other*
503 - Food Science and/or Technology (see also 573)
508 - Forestry
506 - Horticulture
507 - Soil Sciences
515 - Fisheries Sciences
516 - Wildlife Management
518 - Agriculture, General
519 - Agriculture, Other*

MEDICAL SCIENCES

520 - Medicine & Surgery
522 - Public Health & Epidemiology
523 - Veterinary Medicine
524 - Hospital Administration
526 - Nursing
527 - Parasitology
528 - Environmental Health
530 - Audiology & Speech Pathology
534 - Human and Animal Pathology
535 - Pharmacology
537 - Pharmacy
538 - Medical Sciences, General
539 - Medical Sciences, Other*

BIOLOGICAL SCIENCES

540 - Biochemistry (see also 280)
542 - Biophysics
550 - Botany
551 - Bacteriology
552 - Plant Genetics
553 - Plant Path. (see also 511)
557 - Plant Physiology
563 - Human & Animal Genetics
566 - Human & Animal Physiology
569 - Zoology
544 - Biometrics & Biostatistics (see also 055, 670, 725, 727)
545 - Anatomy
546 - Cell Biology
547 - Embryology
548 - Immunology
549 - Endocrinology
560 - Ecology
571 - Entomology
572 - Molecular Biology
573 - Food Science and/or Technology (see also 503)
574 - Behavior/Ethnology
576 - Microbiology
578 - Nutrition & Dietetics
589 - Neurosciences
590 - Toxicology
598 - Biological Sciences, General
599 - Biological Sciences, Other*

PSYCHOLOGY

600 - Clinical
603 - Cognitive
610 - Counseling & Guidance
620 - Developmental & Gerontological
630 - Educational
635 - School
641 - Experimental
642 - Comparative
643 - Physiological
650 - Industrial/Organizational
660 - Personality
670 - Psychometrics (see also 055, 544, 725, 727)
675 - Quantitative
680 - Social
698 - Psychology, General
699 - Psychology, Other*

SOCIAL SCIENCES

700 - Anthropology
703 - Archeology
705 - Communications
708 - Linguistics
710 - Sociology
720 - Economics (see also 501)
725 - Econometrics (see also 055, 544, 670, 727)
727 - Social Statistics (see also 055, 544, 670, 725)
730 - Demography
740 - Geography
745 - Area Studies*
751 - Political Sci. & Government
752 - Public Administration
753 - Public Policy Studies
755 - International Relations
760 - Criminology & Criminal Justice
770 - Urban & Regional Planning
775 - History & Philosophy of Sci.
798 - Social Sciences, General
799 - Social Sciences, Other*

HUMANITIES

804 - History, American
805 - History, European
806 - History, Other*
811 - American Literature
813 - English Language
814 - English Literature
827 - Classics
831 - Speech & Debate
836 - Comparative Literature
839 - Letters, Other*
821 - German
822 - Russian
823 - French
824 - Spanish & Portuguese
826 - Italian
829 - Other Languages*
802 - Art History & Criticism
808 - American Studies
809 - Theatre & Theatre Criticism
830 - Music
833 - Religious Studies (see also 851)
834 - Philosophy (see also 030)
861 - Library & Archival Sciences
878 - Humanities, General
879 - Humanities, Other*

EDUCATION AND PROFESSIONAL FIELDS

801 - Applied Art
851 - Theology (see also 833)
852 - Business & Management
853 - Home Economics
854 - Journalism
855 - Law, Jurisprudence
857 - Social Work
858 - Architec. & Environ. Design
896 - Professional Fields, General
897 - Professional Fields, Other*
838 - Education (other than teaching in a field listed above)

899 - OTHER FIELDS*

*Identify the specific field in the space on the questionnaire.

14. ENGINEERING

14.01 Engineering, General
- 14.0101 Engineering, General

14.02 Aerospace, Aeronautical, and Astronautical Engineering
- 14.0201 Aerospace, Aeronautical, and Astronautical Engineering

14.03 Agricultural Engineering
- 14.0301 Agricultural Engineering

14.04 Architectural Engineering
- 14.0401 Architectural Engineering

14.05 Bioengineering and Biomedical Engineering
- 14.0501 Bioengineering and Biomedical Engineering

14.06 Ceramic Engineering
- 14.0601 Ceramic Engineering

14.07 Chemical Engineering
- 14.0701 Chemical Engineering

14.08 Civil Engineering
- 14.0801 Civil Engineering

14.09 Computer Engineering
- 14.0901 Computer Engineering

14.10 Electrical, Electronics, and Communications Engineering
- 14.1001 Electrical, Electronics, and Communications Engineering
- 14.1002 Microelectronic Engineering

14.11 Engineering Mechanics
- 14.1101 Engineering Mechanics

14.12 Engineering Physics
- 14.1201 Engineering Physics

14.13 Engineering Science
- 14.1301 Engineering Science

14.14 Environmental Health Engineering
- 14.1401 Environmental Health Engineering

14.15 Geological Engineering
- 14.1501 Geological Engineering

14.16 Geophysical Engineering
- 14.1601 Geophysical Engineering

14.17 Industrial Engineering
- 14.1701 Industrial Engineering

14.18 Materials Engineering
- 14.1801 Materials Engineering

14.19 Mechanical Engineering
- 14.1901 Mechanical Engineering

14.20 Metallurgical Engineering
- 14.2001 Metallurgical Engineering

14.21 Mining and Mineral Engineering
- 14.2101 Mining and Mineral Engineering

14.22 Naval Architecture and Marine Engineering
- 14.2201 Naval Architecture and Marine Engineering

14.23 Nuclear Engineering
- 14.2301 Nuclear Engineering

14.24 Ocean Engineering
- 14.2401 Ocean Engineering

14.25 Petroleum Engineering
- 14.2501 Petroleum Engineering

14.26 Surveying and Mapping Sciences
- 14.2601 Surveying and Mapping Sciences
- 14.2602 Cartography

14.27 Systems Engineering
- 14.2701 Systems Engineering

14.28 Textile Engineering
- 14.2801 Textile Engineering

14.99 Engineering, Other
- 14.9999 Engineering, Other

15. ENGINEERING AND ENGINEERING RELATED TECHNOLOGIES

15.01 Architectural Technologies
- 15.0101 Architectural Design and Construction Technology
- 15.0102 Architectural Interior Design Technology
- 15.0199 Architectural Technologies, Other

15.02 Civil Technologies
- 15.0201 Civil Technology
- 15.0202 Drafting and Design Technology
- 15.0203 Surveying and Mapping Technology
- 15.0204 Urban Planning Technology
- 15.0299 Civil Technologies, Other

15.03 Electrical and Electronic Technologies
- 15.0301 Computer Technology
- 15.0302 Electrical Technology
- 15.0303 Electronic Technology
- 15.0304 Laser Electro-Optic Technology
- 15.0399 Electrical and Electronic Technologies, Other

15.04 Electromechanical Instrumentation and Maintenance Technologies
- 15.0401 Biomedical Equipment Technology
- 15.0402 Computer Servicing Technology
- 15.0403 Electromechanical Technology
- 15.0404 Instrumentation Technology
- 15.0405 Robotics Technology
- 15.0499 Electromechanical Instrumentation and Maintenance Technologies, Other

15.05 Environmental Control Technologies
- 15.0501 Air Conditioning, Heating, and Refrigeration Technology
- 15.0502 Air Pollution Control Technology
- 15.0503 Energy Conservation and Use Technology
- 15.0504 Sanitation Technology
- 15.0505 Solar Heating and Cooling Technology
- 15.0506 Water and Wastewater Technology
- 15.0599 Environmental Control Technologies, Other

15.06 Industrial Production Technologies
- 15.0602 Food Processing Technology
- 15.0603 Industrial Technology
- 15.0606 Optical Technology
- 15.0607 Plastic Technology
- 15.0609 Textile Technology
- 15.0610 Welding Technology
- 15.0699 Industrial Production Technologies, Other

15.07 Quality Control and Safety Technologies

- 15.0701 Occupational Safety and Health Technology
- 15.0702 Quality Control Technology
- 15.0799 Quality Control and Safety Technologies, Other

15.08 Mechanical and Related Technologies

- 15.0801 Aeronautical Technology
- 15.0803 Automotive Technology
- 15.0804 Marine Propulsion Technology
- 15.0805 Mechanical Design Technology
- 15.0899 Mechanical and Related Technologies, Other

15.09 Mining and Petroleum Technologies

- 15.0901 Coal Mining Technology
- 15.0902 Mining (Excluding Coal) Technology
- 15.0903 Petroleum Technology
- 15.0999 Mining and Petroleum Technologies, Other

15.10 Construction Technology

- 15.1001 Construction Technology

15.99 Engineering and Engineering-Related Technologies, Other

- 15.9999 Engineering and Engineering-Related Technologies, Other

APPENDIX B

AGENDA

Workshop on Data Needs for the 1990s
National Academy of Sciences
2001 Wisconsin Avenue, NW--Room 130
Monday, March 28, 1988

8:00	Continental Breakfast	
8:30	Welcome	*Robert M. White, president* *National Academy of Engineering*
	Introductory Remarks	*Richard J. Green, assistant director* *Directorate for Scientific, Technological, and International Affairs, National Science Foundation*
	Overview Committee's Task Workshop Objectives	*John P. McTague, chairman* *Committee on Data Needs for Monitoring Labor-Market Conditions for Engineers*
	Engineering Data Bases: Strengths and Weaknesses	*Engin I. Holmstrom, consultant*

American Society for Engineering Education
Bureau of the Census
Bureau of Labor Statistics
Engineering Manpower Commission
National Center for Education Statistics
National Science Foundation
National Society of Professional Engineers

9:30	Major Issues	*John P. McTague*

1. Nature and scope of *Occupational Mobility*: flow dynamics; career patterns of engineers with different educational levels and training; fungibility of the engineering work force; resiliency

2. *Technical Currency:* effects of new technologies/fields on U.S. engineers; nature, scope, and effectiveness of continuing education and in-service training

3. *International Flows:* net effects on U.S. engineering work force; number and types of foreign engineers who enter, leave, or remain in the U.S. engineering community

4. *Women and Minorities*: nature and effectiveness of increasing the participation of underrepresented groups; numbers and utilization patterns of women and minorities; tracking whether participation is increasing

10:00 *Break*

10:15 Small Group Discussions

1. *Occupational Mobility*
   Pam Atkinson
   Jerrier Haddad
   Eric Herz
2. *Technical Currency*
   William LeBold
   Karl Willenbrock
3. *International Flows*
   Michael Finn
   Charles Falk
   Dael Wolfle
4. *Underrepresented Groups*
   Betty Vetter
   Alvin Bernstein
   Donald Weinert

12:15 *Lunch in Refectory*

1:15 Panel Presentation: Reconciling the Data Bases to Respond to the Major Issues
Pam Atkinson, Michael Finn, William LeBold, Betty Vetter

2:00 *Open Discussion*

3:00 *Break*

3:15 *Open Discussion*

4:30 Summary
Concluding Remarks *John P. McTague*

APPENDIX C

PARTICIPANTS

Workshop on Data Needs for the 1990s
National Academy of Sciences
2001 Wisconsin Avenue, NW--Room 130
Monday, March 28, 1988

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APPENDIX D

SUMMARY OF DISCUSSION

Workshop on Data Needs for the 1990s
National Academy of Sciences
2001 Wisconsin Avenue, NW--Room 130
Monday, March 28, 1988

John P. McTague, chair of the committee, welcomed workshop participants and introduced Robert M. White, president of the National Academy of Engineering, who spoke about the importance of the committee's task. Next, Richard Green, assistant director of NSF's Directorate for Scientific, Technological, and International Affairs stressed the importance of the workshop to the Foundation in planning its statistical activities for the 1990s.

Introduction

Dr. McTague stated that both the committee and NSF are interested in the information that properly collected data can give in order to enable one to formulate policy. Of particular interest are data from which one can analyze trends and flow patterns--not static data, which present a snapshot of a given field at a given time. He said that although several of the data bases use different definitions of "engineers," resulting in apparent discrepancies (some of that has to do with who defines the engineer--whether the engineers is defined by his/her education or licensing, whether defined by the individual in terms of functionality, or whether defined by the employing company or enterprise in terms of functionality), that is the small part of the issue. The larger part of the issue is how to collect data that are useful for government, industry, and academe to utilize for determining policy, in order to respond effectively in these areas and to compete in a global environment that involves rapid technological change. That depends upon what the facts are, and in many cases, to extract the facts that one is interested in from current data bases is very difficult.

As an example, Dr. McTague noted that many of the functional research engineers in the United States actually have advanced degrees in the physical sciences. What are the implications of this for the support of science education, as well as for the support of engineering education? What might we expect for future supply and demand trends in subfields of engineering, such as computer science, electrical engineering, and mechanical engineering? What are the implications of the changing technological environment as far as continuing education and retraining of workers? What data indicate the amount and the effectiveness of such continuing education?

He also asked, "How can one predict the demand for various fields of engineering as one allocates resources that will have impact on universities for decades to come? How can we utilize all of the human resources of our country most effectively--namely, increasing the involvement of minorities and women?" He noted that these are some of the questions that the study committee decided to focus on: rather than either to look at the data bases themselves individually or to correlate them into a more useful pattern, the committee determined that to discuss what data would be useful and important for policy makers in government, industry, and academe and (by interacting with those who are experts on the data bases) to figure out what can be extracted from present data bases, how the data bases should evolve in order to become more useful, and how they can be correlated.

Overview of the Data Bases

Dr. Engin Holmstrom, consultant to the study committee, gave an overview of her examination of the engineering data bases. In talking about the strengths and weaknesses of the different data bases, she stated that each data base is strong in the sense that it meets the purpose for which it was designed. She believes that integration of these data bases into a single comprehensive data base is an ideal notion impossible to implement. One can use different data bases and analyze the data in such a way as to answer questions for which they perhaps had not been designed.

She explained that one reason for the differences in estimates of engineers in the various data bases comes from how "the engineer" is defined in each. For instance, the Bureau of Labor Statistics (BLS) definition is more occupation-specific, since most BLS data is obtained from industry. For example, BLS asks employers to give the numbers of people in certain job positions, and whoever is in that particular job is counted as an engineer. Whether that person has been trained as an engineer or meets the academic credentials required by a licensing or credentialing organization doesn't affect his/her being considered an engineer. If an individual does an engineering job, then he/she is classified as an engineer. On the other hand, the National Science Foundation (NSF) has a very complex way of defining engineers that differs greatly from the way that BLS defines them; methodological differences in the BLS and NSF surveys also lead to inconsistent counts of the number of engineers. Most BLS surveys are establishment surveys, while NSF surveys individuals. The difference becomes very important when one asks certain questions and analyzes them. Some cross-tabulations of data are impossible, particularly in employer surveys, because the same questions are not asked in all surveys.

Furthermore, not every data base is designed to provide different levels of information. Surveys of both individuals and employing establishments provide enumerative information. However, descriptive information can be obtained only from surveys of individuals. Similarly, much of the analytic information of interest to policymakers is derived from surveys of individuals. The usefulness of the enumerative information depends on how representative the studies are.

Descriptive and analytic information, on the other hand, can be obtained from smaller studies, but the sample of respondents should be representative of the whole group. For instance, the National Society of Professional Engineers (NSPE) conducts an annual survey of income of its 60,000 members, but that is neither representative of the entire engineering community nor generalizable to the NSPE membership because the response rate is only 24 percent.

The Engineering Manpower Commission (EMC) has a series of very strong data bases that provide annually the number of students enrolled in engineering and technology programs, information on engineering and technology degrees, information about salaries of practicing engineers and academic engineers. Their establishment-based surveys provide tabulations but do not allow for cross-tabulations.

The American Society for Engineering Education obtains rather comprehensive information about engineering students and faculty from all of the engineering schools.

The National Center for Education Statistics (NCES) has been collecting data on enrollment and degrees for over 20 years, but its data bases are not 100 percent comparable to what EMC, for instance, has. Because NCES is expanding its data base in the 1990s from 3,000 to 13,000 higher education institutions, Dr. Holmstrom expects some delays in making the data available but reserves judgment on the data's usefulness. The largest change will be in data on training awards below the baccalaureate.

The Bureau of the Census and Bureau of Labor Statistics (BLS) are two other major data sources. The Bureau of the Census conducts the decennial census, which NSF uses to draw its sample for the postcensal survey and the subsequent surveys of experienced scientists and engineers. The Census provides the National Science Foundation (NSF) the number of who say they are engineers and scientists in that particular decennial year. NSF then checks for degree, augments the sample with others who have college degrees, and ultimately arrives at a sample of scientists and engineers that is the base for the next four biennial surveys. BLS uses the Occupational Employment Survey (establishment/industry-based) and Current Population Survey (monthly household interview) to obtain information on engineers. The CPS includes questions that one can tease--for instance, to find out if an engineer has gone to the technical reserve or to answer some of the mobility questions.

The data bases of NSF are the most valuable for analytic information because follow-up surveys are conducted. However, in some surveys the sample sizes are too small for one to look at what a certain subcategory or subspecialty of engineer is doing. NSF surveys, however, provide much information that is not usually reported from the data bases of other collection agencies. In fact, NSF is interested in learning what kinds of collected but unreported information would be most useful to the engineering community. Also, the NSF data could be analyzed differently to provide answers to different questions.

Discussions

Before the participants met in small groups, Dr. McTague noted that the individual discussion groups should formulate for themselves the character of the issues believed to be the most important ones for the coming decades. Each group was asked not to define its activities narrowly but, rather, in terms of the priority questions that could be answerable either from existing data bases or from appropriately designed or expanded data activities. The study committee was particularly interested in data that can be used to determine trends. What kind of data should we have to determine, for example, typical undergraduate education in engineering? Thus, each group should determine a small number of questions having very high priority that are related to data about the specific issue examined by that one group and then discuss how each question relates to existing data bases, how it might relate to expansion or correlation of existing data bases, or how it might require some special study. The first thing is to discuss, within the broad area given to each particular discussion group, the small number of the most important areas for the next decade or two, those on which factual information is needed in order for policymakers to act rationally.

Dr. Charles Falk, a member of the study committee, noted that neither the committee nor the workshop was created to make projections about engineering supply and demand; instead, the emphasis is on determining what kind of data are needed to answer questions related to these subjects.

Mr. Alan Fechter, executive director of the Office of Scientific and Engineering Personnel, reviewed guidelines for the small-group discussions:

(1) The more general the information that is being required, the more important it is (if, for instance, we are asking for information that cuts across all fields, cuts across all industries, cuts across all regions of the country, that seems to be the highest level of information);
(2) Consideration should be given to the difficulty of the resource requirements that would underlie acquisition of the requested information (trying to create a massive data base that would allow us to describe the engineering community as a totality could be a massive undertaking requiring large amounts of resources);
(3) Finally, each group should bear in mind the importance of the issues being addressed by their questions.

Following the small-group sessions, the leaders of the small groups shared with the other workshop participants the character of the discussions and the particular priorities and action items that they had delineated. The following paragraphs summarize the reports of the individual discussion groups, as well as open discussions on each topic deemed to be a major issue: occupational mobility and flow dynamics, international flows, maintaining technical currency, and underrepresented groups in engineering.

Occupational Mobility

Ms. Pamela Atkinson, former NAE fellow now at the University of California-Berkeley, said that the group on occupational mobility delineated three specific areas of emerging concern:

(1) The need to refine and redefine very carefully the survey questionnaires because the data necessary now to determine future requirements do not really address specifically enough the needs of the researchers, who are concerned about (a) the educational path of the young engineer, (b) the subjective and economic concerns of that engineer, (c) the potential career flexibility that might be possible for that engineer, and (d) the time lapse between when a

problem is identified and when intervention can take place, in terms of either education or career mobility.

(2) The need to define "engineer" less in terms of discipline and more in terms of function.

(3) The need for data-collection agencies to gather information in more detail, to develop mechanisms to link the various components of that information to data bases elsewhere, and to disseminate the information better.

The discussion group noted that data are needed on the rates of movement of engineers with various degree levels. For instance, those enrolled in graduate school should be defined more specifically: who are enrolled in M.S. programs, who are enrolled in Ph.D. programs, how many years out they might have been before they reentered the school system, are they continuing with the master's degree right after the bachelor's, are they resident or nonresident students, how is their education financed?

Mr. Jerrier Haddad, a member of the study committee and chair of the earlier Committee on the Education and Utilization of the Engineer (CEUE), added that participants felt that NSF data should be more career-oriented and that the BLS data would be substantially more useful if it contained elements implicit in the NSF data--namely, education specialty. Dr. Michael Finn, of Oak Ridge Associated Universities at the time of the workshop and now director of studies and surveys in the National Research Council's Office of Scientific and Engineering Personnel, agreed that the study committee's report should deal with the importance of forcing more consistency in occupational classification within the data bases. Dr. William K. LeBold, director of engineering education research studies and information systems at Purdue University, suggested improving the current taxonomy of engineering by adding functions in which engineers are employed--including design, operations, and consulting--as well as level of responsibility, technical or supervisory. In response, Dr. Charles Dickens, head of the Surveys and Analysis Section of the Division of Science Resources Studies in NSF's Directorate for Scientific, Technological, and International Affairs, noted that in some surveys, NSF has experimented with getting more information on the type of employer but that it is very difficult for individuals to assign the same employer categorization as would be assigned by BLS. He added that more information on career changes can be obtained from NSF's longitudinal surveys through repeatedly surveying the same individuals about their change in status. He said that because both engineers and scientists are surveyed by NSF in a single questionnaire, the Foundation would also need to discuss with representatives of the scientific community how questionnaires might be designed to provide more of this information.

Dr. Robert Weatherall, director of career services at Massachusetts Institute of Technology, said that it was a question not only of gathering data for policy purposes, but also of helping the engineering community to know itself better.

International Flows of Engineers

Dr. McTague noted that becoming more and more important is how the federal government will approach the issue of foreign engineering students. Is it good to have more than 50 percent of the students in some graduate engineering departments from other countries? Is having a high proportion of foreign students intimidating to American students? What are the implications of this for our immigration policy; should we encourage these students to stay after receiving their education? What are the implications of global technological alliances? In fact, the engineering work force that is being used by corporations in the United States does not rest just in this country at all; what are the implications of that?

He noted that the area of international flows is quite important, but data are very difficult to acquire. The question of comparability is compounded, and the data are very highly aggregated. Foreign personnel data collected by OECD are very highly aggregated and are limited in scope, reporting only scientists and engineers engaged in R&D. NSF has made strides to provide information disaggregated by occupation and activity, but these data are not readily available in the countries themselves. Thus, getting the information out that one wishes is almost impossible at present. He noted that the CEUE addressed the importance of flow data by devising a fairly complete model of the major inflows and outflows of engineering talent. Unfortunately, no single data base provides all of these pieces of information. He suggested that the workshop participants could help by pointing out certain areas where the flow information is obtainable or would be obtainable with a finite degree of effort.

Mr. Haddad noted that international flows are inextricably linked with alliances and gave examples from the automotive industry.

Dr. Finn stated that the group on international flows of engineers examined policy issues. Data from the Survey of Earned Doctorates dealing with current measures of the inflow of foreign engineers earning degrees from U.S. institutions are reasonably good; and beginning with the 1987 Survey of Doctorate Recipients, NSF is improving the follow-up procedures for persons with foreign addresses. But, Dr. Finn noted, Ph.D.s comprise a tiny fraction of the engineering labor pool. For people below the Ph.D. level, not until the 1986 Survey of Recent Graduates were persons with foreign addresses included. The group did endorse NSF's conducting of an immigrant survey and suggested that NSF keep the foreign B.S. and M.S. graduates in the Recent Graduate Survey in spite of nonresponse bias for people with foreign addresses at the time of their graduation.

A related question to this inflow was that firms, because they have been having greater difficulty certifying foreign engineers to work in the United States recently, may be sending more work abroad. We don't know to what extent we can measure the import and export of engineering services. Special surveys of employers by NSF in the recent past dealt with questions relating to foreign nationals. The discussion group endorsed the idea of another survey that asked employers specifically about foreign-born engineers employed in the United States and abroad and about the import and export of engineering services, for measuring not only these flows, but also the impact of flows within corporations.

The question of how long foreign engineers stay when they come to the United States has been examined, but little published information is available. As to the question about where the engineers come from, the basic data elements are there, but generating the data is complicated and difficult because concerns about confidentiality usually preclude their release by NSF and the Bureau of the Census. Some country-of-origin data are available from the Survey of Doctorate Recipients, but such data are not always tabulated on a regular basis.

What factors promote the flow of foreign engineers to the United States? Research evidence indicates that economic, social, and political factors are quite important. The findings of social scientists that political freedom, for example, is an important determinant as well as economic factors certainly should not be overlooked; evidence shows that those who are supported by their own governments are more likely to return than those who are not supported by their governments.

The existing data on the flow or interaction of American engineers with foreign engineering enterprises are inadequate and anecdotal. However, the 1987 Survey of Doctorate Recipients has a series of questions asking Ph.D.s to indicate whether they have made trips abroad for 3 or more months in some recent period of time and to describe somewhat their involvement with foreign work. If the results appear to be useful, the discussion group felt that it may be quite worthwhile to do something similar for the B.S. and M.S. graduates in surveys that NSF conducts, noting that B.S. and M.S. graduates comprise the vast majority of engineers. There may also be some possibilities for exploring existing data sources: DoD and DoE laboratories and contractors have security requirements that cause them to keep track of who goes abroad; some foreign consulates award visas to U.S. citizens; the IRS might have useful data if people take tax deductions for expenses associated with working away from home; U.S. companies might be queried on data for these visits. In addition, we can and should continue to look at foreign immigration statistics (other countries keep track of who comes into their country as immigrants, even for short-term visits).

The impact of foreign engineers on salary levels is a difficult but important question that has not really been adequately researched, although data exist.

What happens to foreign national students who don't stay here is relevant, even if one focuses on the U.S. work force, because foreign nationals earning degrees in the United States seem to be important contacts for people who are here and such information is relevant to technology transfer and international competitiveness. However, the discussion group recognized that trying to keep foreign students who don't stay in the United States in the sample Ph.D., M.S., and B.S. populations would be costly. The Ph.D. survey doesn't include people who assert at the time of graduation that they have firm plans to work abroad; although that is a small fraction of the Ph.D. population, the feasibility of keeping them in the follow-up surveys should be considered by NSF because of the cost of educating these people and the possible benefits of interacting with them around the world.

The discussion group saw international comparisons as a valuable addition to trend data. NSF has started an ambitious program, with the help of the U.S. Census Bureau, to get (from foreign census bureaus) information on the numbers, occupations, and characteristics of scientists and engineers for the large industrialized countries. The group felt that this effort should continue. In addition, information on the emigration of American engineers should be sought from foreign census bureaus.

Dr. Dael Wolfle, liaison to the study committee from OSEP's Advisory Committee on Studies and Analyses, agreed that we still have much better data on the engineers who are trained here and stay here than on those elsewhere who are influential here. One of the major data gaps is the difficult one of keeping track of people who were here but have gone elsewhere; in multinational corporations, information transfer combinations are still effectively part of our system, which must be brought up to date with the reality. Dr. Falk added that the need for data on foreign students who leave the United States was given fairly high priority from a policy point of view because the real issue, especially in state-operated universities, is whether subsidies are provided to foreign engineering students. Furthermore, we don't know what happens to those who leave and go to other countries: do they establish or maintain important U.S. contacts and enhance cooperation, or do they foster competition?

Dr. Falk emphasized the high priority given by the group to learning to what extent Americans go abroad: this seems relatively feasible because it involves extending an existing survey. It would provide useful data on another very important policy issue--namely, what is the dependency of the United States on foreign engineering talent?

By the same token, Dr. Falk noted that the third question was even more difficult: What effect will the presence of foreign engineers or immigrant engineers have on the culture of the activities in various institutions? To what extent will they be a major presence in academic institutions and affect curricular development? To what extent are they present in industrial institutions and changing the mode of engineering that is done? Essentially, he said, the engineering community needs to know where foreign and immigrant engineers are in the United States. Not all such questions are answerable strictly by the data, however.

Dr. Howard Adams, executive director of the National Consortium for Graduate Degrees for Minorities in Engineering, Inc., asked whether the increased level of foreign assistant professors changes the culture of a school. In response, Dr. Finn explained that an NSF-sponsored survey of graduate faculty and graduate departments obtained actual numbers and their perceptions of the impact of large numbers of foreign graduates in engineering departments. It did ask, for example, the extent to which any of their work had been constrained by security considerations, but it did not attempt to determine the implications for later professional practice of large numbers of foreigners in graduate engineering departments. Dr. McTague said that the group discussing international flows did take up the problem of foreign faculty and foreign teaching assistants, particularly as they affect women and minorities, and in terms of their language capabilities. Dr. Wolfle and Dr. Falk agreed that the issue of foreign engineering students and faculty must be pursued further. Ms. Jennifer Bond, study director of the International Studies Group in NSF's Division of Science Resources Studies, noted that this discussion group also considered the possibility of doing a special study about these trends within multinational companies themselves, that this is a large part of the reality of today's environment compared to traditional ways of measuring nation, state, and citizenship.

Dr. Falk added that another issue is to get more information on what limitation the defense establishment's activities have experienced due to the fact that, generally, foreign engineers and, in many cases, immigrant engineers cannot be employed or utilized on defense projects.

Finally, the group discussed the question of integration of the various data bases. The NSF postcensal survey is almost perfectly integrated with the 1980 census population. The area where lack of integration i most commented on is between NSF and BLS, and the discussion group reached no consensus.

Technical Currency

Dr. LeBold explained that the group discussing technical currency addressed the general problem of defining "technical obsolescence." The current surveys provide relatively little information about it, but correlates of technical currency include level of responsibility (technical or supervisory), degree level, activities engaged in (ranging from simple discussion to patents or publications), and sources of information. He noted that informal acquisition of information is probably used much more extensively than formal, continuing education and that we need to be able to address how engineers at different levels and performing different functions acquire information informally. While current surveys can not necessarily provide information about this informal education, probably some targeted in-depth studies could. Dr. Karl Willenbrock, a member of the study committee, added that no data base provides information about how well somebody really does a job. There was a feeling that if we had a good system for career-long education, we could raise performance levels. The small-group participants also examined technologies and the critical areas that should be addressed.

The current surveys would provide minimal information about fungibility if one looks at field of major or highest degree and relates that to current functions or current fields.

Resiliency itself can't be analyzed from current data, but correlates of various activities might be conducted, particularly in pilot studies. While some of the professional engineering societies do conduct studies that provide data about the level of technical responsibility, their current surveys provide very limited information about technical obsolescence.

...ter summarized the group's discussion about four points:

(1) Utilization: Do we understand well what engineers do, and what does our information system tell us about utilization of engineers (field in which they are working, activities in which they are engaged, the level of responsibility within those activities)? Some useful information already is collected. We know the fields, although taxonomic problems of respective fields should be addressed, and questions have been raised about whether the taxonomy of work activities is appropriate and adequate to fully understand what people are doing. In addition, information is lacking on level of responsibility of engineers.

(2) Lack of data about technological change and emerging fields: Surveys of individuals are not useful in identifying areas in which technology is changing rapidly or in which fields are emerging dramatically. Delphi techniques, perhaps workshops of experts who would provide expert opinion about what is happening, or case studies looking at these issues might be better.

(3) Training or educational activities that enable engineers to deal with these changes: How do engineers accommodate emerging technologies and developing fields? The general feeling was that the current survey instruments emphasize heavily the credit courses, both formal and informal, but give insufficient weight and attention to the very elaborate set of informal activities of engineers--such as symposia, meetings, conferences; reading journals; talking to colleagues--by which engineers keep themselves up to date. He felt that personal surveys of engineers should ask about the amount of time that they spend at these various activities.

(4) How to assess whether skills are deteriorating or improving: Possible indicators might be papers given at international meetings, patent citations, and salary of an individual engineer as well as the profitability of the employing firm.

Dr. LeBold felt that skills could be assessed by relating salary, educational level, and function to other measures such as activities and sources of information. Maybe some research should be conducted so that more adequate measurement techniques are developed. Mr. Fechter stressed that enumerative data are necessary before one can ask relevant questions about what they mean.

Underrepresented Groups

Dr. McTague asked, "What are the numbers and characteristics of women and minorities who enter engineering? Does the word 'enter' refer to K-12, or to college freshmen, or to the labor force of engineering graduates?" Information on the K-12 system is insufficient, and we know very little about changes in course-taking over the past several years. The High School and Beyond study examined the class that graduated from high school in 1980, but we don't know what has happened since. Engineering degrees and enrollments are decreasing, in percentage terms, more sharply for women than for men. Therefore, the 15 percent of women now enrolled in engineering is not going to hold. We are very concerned with the need for timely data, particularly at this point.

Ms. Betty Vetter, executive director of the Commission on Professionals in Science and Technology, felt that if women are going to drop out of engineering faster than men, we need to know their reasons; age-group demographics are only one reason. Such information would not be obtainable from a data base; individual studies of individual people and a continuing longitudinal tracking of undergraduate students, both those who succeed and those who do not, seem imperative to her. She advocated more internal studies by institutions of their retention patterns for minorities, women, and men--such as those conducted by the University of Washington and Northwestern University, for example. Furthermore, she said, if we find out what keeps minorities in the pipeline, we will also find out what keeps white males, who are increasingly dropping out. She mentioned several engineering data bases not listed in Dr. Holmstrom's background paper that might be helpful in analyzing some of the questions: (1) the Association of American Colleges' data base, just beginning in 1986, will have information on undergraduate coursework at 35 institutions, (2) the Boy Scouts of America conduct an annual survey in American high schools to find people, both boys and girls, interested in its Explorer program, (3) the federal government collects data on employment of federal scientists and engineers, in particular for the Federal Task Force on Women, Minorities, and the Handicapped. One, for example, surveyed a matched sample of Ph.D. scientists and engineers in federal employment in 1977 and still employed in 1988 to see if they had improved salary relationships. She noted that they had not: women, on average, earn consistently lower salaries than white or Asian men in 1988, as was also true of their starting salary levels in 1977.

According to Ms. Vetter, the only data on utilization patterns for women and minorities are from BLS's occupational survey and the NSF estimates, but she cautioned that BLS inevitably shows a proportion of women and minorities in any engineering population at approximately twice what the NSF proportions are. The other source for utilization data is NSF, but because the sample cells are so small, we know very little. Ms. Vetter said that her discussion group felt that the question of barriers for both women and minorities could not be answered by the current data bases. However, changing the taxonomy on which the data bases operate--using occupational classification of what the engineer does rather than the traditional academic field--might provide useful information. What we need are many more individual studies in which a group of targeted people are asked, "Why is this so? Why did you drop out of engineering?" She cited such a study of 176 women engineers who have decided to leave engineering after working in the field for several years. In addition, we need studies to find out more about what happens to minorities who start but don't finish--that is, do minority men and women differ in their persistence?

The session on underrepresented groups in engineering felt that after some longitudinal, individual studies, we need a clearinghouse where the information can be compiled and then disseminated. The discussion group's second biggest recommendation is to fund individual studies and then to disseminate the information. It was recommended, for example, that the National Science Foundation fund data activities of the National Society of Black Engineers.

Mr. Donald Weinert, a member of the study committee, focused on three areas:

(1) Doing more tracking via longitudinal work because current data bases and collection efforts do not provide the kinds of answers that will allow decisionmakers to get at the policy issues,

(2) Coordination of efforts through a clearinghouse, and
(3) Getting more minorities and women into faculty positions.

He noted that most women and minorities in graduate engineering aspire primarily to the master's level and not to the Ph.D., the prerequisite to attaining faculty tenure. Yet all of the systems that we have are more aimed at getting people onto the Ph.D. track because that is the entry level for faculty. Thus, we might be overlooking a whole group of people who are really just focused on the master's level.

Dr. Alvin J. Bernstein, a member of the study committee, added that one data gap is that in making the counts of minorities and females, we are unable to identify in any of the existing surveys "black females." The counts are usually either by sex or by race/ethnic group. Those data are clearly in some individual data bases but are not reported with such fine breakdowns. In several important data bases, such as EMC's enrollment and degree studies, the data are not even collected except for head counts by sex and by minority group.

Mr. Eric Herz, another member of the study committee, asked, "If one of the subjects were how to attract minorities and women into engineering schools, would the data be useful to relate the qualities and the qualifications of the high school science and math teachers and their role models? Would that be a useful way to find out which are the successful black students in a university and which are not?" Ms. Vetter responded that information on the qualifications of high school science and math teachers would be useful for several reasons, but is not available. Dr. Bernstein felt that such issues would not be addressed by a national data base.

Mr. Fechter asked, "What information do we have on the question of dual careers and their impact on enabling women, in particular, to successfully compete and move up the ladder in careers in science and engineering?" Again, Dr. Bernstein pointed out that understanding that phenomenon requires small intensive studies of populations in the field rather than reliance on data bases.

General Comments

Dr. Richard Valentin, program manager at Argonne National Laboratory, questioned the validity of surveys and suggested that much more reliable data could be obtained from a sampling technique that followed up on it. Several workshop participants agreed that continuity is a critical issue. In the same vein, Dr. McTague believed that the use of existing data bases by clever manipulation or minor extension is clearly preferred to the creation of a whole new class of studies.

Mr. Haddad expressed concern about the lack of rationalization of what happened to create different numbers in the various engineering data bases. Mr. Herz concurred that being able to relate differences in the data bases is very important.

Ms. Vetter felt that some data don't get used as much as they could. For example, very little analytical work is done on the Ph.D. data collected by the National Research Council for the National Science Foundation. In response, Mr. Neal Rosenthal, chief in the Bureau of Labor Statistics' Division of Occupational Outlook, said that the National Center for Education Statistics has followed up the high school class of 1972.

Dr. McTague focused on the kinds of questions to which answers are important and to which data are relevant. When asked for other issues that the data bases should address, Dr. Peter Cannon, vice president for research and chief scientist at Rockwell Science Center, cited recognition of the present reality --one of comparative shortages in which employers are seeking to increase productivity of workers by sharply increased capital investment per employee--as very important. In virtually any study of any labor market, one would make an inquiry as to that investment because it is a significant variable impacting the labor market. Incorporating a sense of this reality in the context of the delivery of engineering services will elucidate a powerful external variable impacting all of these questions of what happens to people.

Mr. Haddad added that citing examples of national issues on which data are lacking would aid the understanding of the issues by nonprofessionals in the field. Dr. Dickens suggested that the committee mention the usefulness and importance of continuing many of the data-collection efforts; he said that focusing only on gaps might imply that some of these ongoing efforts could be sacrificed. He noted that NSF has identified some major data gaps, which it is trying to address. For instance, NSF is working with the Immigration and Naturalization Service to get much more information about immigrant scientists and engineers.

Dr. Weatherall spoke of a need for more consciousness of the engineer in entrepreneurial small companies and the use of engineers in roles that have not been thought of, historically, as strictly engineering roles--such as sales. He cited two different interests: (1) the engineer in engineering and (2) the engineer as a person. Ms. Vetter discussed the difference between WHAT an engineer is and WHO an engineer is. She felt that the committee should determine whether it would recommend changing the way in which NSF identifies who belongs in the sample as the next generation of data comes out, starting with the 1990 census. Mr. Fechter expressed the participants' view that each data base should be maintained as flexible as possible so that one can look at whatever group of engineers is deemed appropriate to the problem examined. When preparing its postcensal survey, for example, NSF must not exclude people that it will later regret excluding because they cannot be picked up once the sample has been established.

Dr. Falk recalled steps taken by NSF to create a more detailed taxonomy for computer specialists; a group representing industry and academe designed a more suitable taxonomy without seriously damaging earlier ones. Dr. Dickens noted that this more detailed classification system of employment in computer fields was designed to preserve the continuity of the data system. He added that the Department of Labor and the Bureau of the Census participated in the development of the new taxonomy and are now conducting studies to see if they can implement it in their own data-collection systems, thereby making the taxonomy much more useful.

Dr Finn suggested that the current taxonomies could be supplemented by examining employment ads to see what employers are asking for. The group concurred that the committee should recommend something that tends to be supplemental to, rather than replacement of, current taxonomies. Dr. LeBold suggested that small pilot studies could be conducted or sponsored by NSF, the Bureau of Labor Statistics, or the National Center for Education Statistics to examine more comprehensive taxonomies in engineering.

Dr. Fred Schulz, section head for R&D recruiting at Procter & Gamble, valued the longitudinal aspect maintained even when questions are added to existing surveys, but suggested that the study committee continue its work and design the ultimate survey that maybe a decade or two from now could replace half the surveys. Dr. McTague felt that by emphasizing the increased importance of longitudinal studies, we are starting to move in the direction of a fully useful, dynamic model. He hesitated to argue for something global.

Dr. Dickens noted the importance of keeping in mind that all of the data collection doesn't have to be on one questionnaire or in one survey. NSF has several surveys--institutional, individual, and quick-response--and also uses information collected by other agencies. There is a wide range of approaches available for use in relating the collected data to the identified issues.

Mr. Haddad suggested a formal mechanism to bring people together to discuss various issues relating to the engineering labor market, perhaps a roundtable; he foresaw the need for one organization to convene regular meetings, perhaps annually, of data collectors. Mr. Richard Ellis of the Engineering Manpower Commission agreed that orchestration is needed some place with all this effort; there are many separate pieces to be monitored and managed. Ms. Vetter agreed with that concept, adding that a central location for housing such collected data is essential.

Dr. Weatherall recalled Lee Hansen's suggestion during the earlier study of the impact of defense spending on engineering employment: Dr. Hansen had suggested that individual universities be encouraged to conduct studies of their own alumni to assess such issues as the migration of alumni between defense and nondefense work.

In summary, Dr. McTague noted that the study committee's report will address the fact that this is a rather limited study that makes no attempt at being comprehensive, but in which the committee tries to focus on some very important areas where dispassionate information is needed for important policy decisions and where the information will have lasting value to serve policy makers and the various engineering sectors in the United States for several decades. Discussion of the four groups at the workshop will serve as the basis for the report, with the committee's recommendations stated around the four broad issues: occupational mobility and flow dynamics, international flows, technical currency, and underrepresented groups in engineering. Based on input at the workshop, the committee will (1) point out that each data base serves separate sets of functions rather well, (2) propose that modest changes in some of the data collection by addition, rather than by total revision of what already exists, will be valuable, (3) emphasize that, rather than trying to make their definitions similar, the data-collecting agencies should obtain modest additional information that will increase the correlative value of the data bases.

Dr. Finn added that the committee should also recommend the frequency at which the data should be collected, and both Dr. McTague and Dr. Dickens agreed. Ms. June Chewning, senior manpower analyst in the Department of Energy's Office of Energy Research, thought that some questions within the surveys could be asked alternately to divide costs--for example, the question of mobility might be examined only every 4 years. Ms. Vetter suggested that no more than 2 years elapse in the cycles of questions in order to make the data most useful and to encourage respondents to retain and report in each survey cycle.

Dr. Wolfle was impressed that all of the small groups emphasized a need for information rather than for data, for understanding the dynamics of the situation. That means more studies of a qualitative, accumulatively longitudinal nature.

In conclusion, Dr. McTague summarized four cross-cutting issues that emerged from the deliberations of the workshop:

(1) The need to evolve the taxonomy in the various data bases so as to emphasize what people actually do as opposed to their academic disciplines, making the data bases more functional,
(2) The value of longitudinal studies in every area,
(3) Making existing data bases more correlatable with each other without harming the accumulated information that exists in them (that implies additional questions that will have to be thought out more carefully to provide cross-cutting data so that the rest of the factors can be correlated), and
(4) The need for special studies that contain information other than pure data.