Engineering and Scientific Manpower: Recommendations for the Seventies (1973)

Pages
56

Size
5 x 9

ISBN
0309344409

Committee on Engineering Manpower Policy; National Academy of Engineering

NATIONAL ACADEMY OF ENGINEERING

Report on

ENGINEERING AND SCIENTIFIC MANPOWER:

Recommendations for the Seventies

ERRATA

Page 12, Table 1: Employment and unemployment, 1967-1971

The numbers given for employed and unemployed engineers in this table are in thousands; the unemployment rate is given in percent.

Engineering and Scientific Manpower

RECOMMENDATIONS FOR THE SEVENTIES

Report of the
COMMITTEE ON ENGINEERING MANPOWER POLICY

NATIONAL ACADEMY OF ENGINEERING
WASHINGTON, D.C.
1973

Available from PPO

National Academy of Engineering
2101 Constitution Avenue
Washington, D.C. 20418

Printed in the United States of America

Order from
National Technical
Information Service,
Springfield, Va.
22151
Order No. PB 222 472

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Preface

In mid-1971 the National Academy of Engineering established the Committee on Engineering Manpower Policy to study the effects of the underemployment of scientists and engineers and to identify the major factors affecting their utilization. Information from members of the Academy and representatives of various segments of industry and government confirmed the Academy's belief that there is a need for effective national policy and planning as a basis for optimum utilization of the technical manpower resource in the United States.

The Committee commenced operations in October 1971. In addition to several meetings of the full Committee, occasionally its members divided into task groups to study specific aspects of the problem of underutilization of engineers and scientists, such as the movement and re-employment patterns of engineers, the availability and dependability of data, and long-range effects and possible solutions for underemployment. By late fall of 1972, the Committee reached its conclusions and, with the help of Dr. Seymour Wolfbein, Dean of the School of Business Administration at Temple University, drafted its report and recommendations.

The report addresses what the Committee considers to be three areas of primary concern in establishing a long-range policy for the effective utilization of technical manpower in the national interest. These are:

- *Dependable and timely information.* Valid comprehensive data on current manpower trends, valid translations of policies and programs into their manpower implications, and valid models for forecasting manpower demand and supply.
- *An effective procedure for planning and decision making.* Consideration by the executive branch of the government on a deliberate methodical basis of the manpower consequences of its current actions as well as of proposed changes in policies and programs at both the executive and legislative levels.
- *Educational programs and economic benefits.* To ensure the continuous availability of an effective technical manpower resource for the nation and to improve manpower mobility during periods of transition of national priorities affecting technical employment.

The Committee did not undertake the study of related manpower issues such as the imbalance of minorities employed in engineering and science or the effects on manpower supply and demand in the United States resulting from the migration of engineering and scientific professionals to this country. Furthermore, because of the degree of incompleteness of the available data base, the Committee was unable to differentiate between engineers and scientists who have received baccalaureate degrees and those without such degrees who nevertheless identify themselves as engineers and scientists. There are cogent questions associated with each of these aspects of the overall problem, and they represent pertinent subjects for further study.

The recommendations of the Committee presented in this report should be viewed as primary steps to initiate further action on manpower issues by government, industry, educational institutions, and professional societies, as well as by the individual engineer or scientist. It is perceived that in spite of the recent upturn in the economy and the accompanying employment opportunities for scientists and engineers, there is still an urgent need for the implementation of the Committee's recommendations. It is recognized that, in the process of their implementation, many of the recommendations will require an expansion in detail with concomitant further study of various related questions. The following questions are illustrative of the further necessary consideration in depth: What should be the specific elements of a national policy concerning retraining? How much should be allocated for re-education and retraining? What would be the substance of these activities? Through what specific programs could the stabilizing of the flow of persons through the educational system into scientific and technical positions be achieved? Are incentives to scientists and engineers to move from one region of the country to another or from one professional specialty to another appropriate and, if so, what should be the nature of those incentives? What is the responsibility of the engineer or scientist to himself for his future; e.g., his willingness to relocate and to keep his professional knowledge up to date? What is a corporation's responsibility to its scientists and engineers, not only with respect to such job benefit issues as portability and vesting of pensions but also in encouraging and supporting professional growth? It is the hope of the Committee that its report will stimulate action on the part of the institutions identified above, leading to concerted effort and subsequent accomplishments in the more effective utilization of technical manpower for the good of the nation.

The Committee is indebted to Dr. William Kelly, Director of the Office of Scientific Personnel, National Academy of Sciences, who participated in the Committee sessions and whose recommendations were gratefully received; Dr. James H. Mulligan, Jr., Executive Secretary, National Academy of Engineering, who attended many sessions and whose advice and support were most helpful; Mr. Robert F. Manske, whose writing gathered the thinking of the Committee; Mr. Joseph F. Malaga and Mr. Ronald M. Konkel of NASA, who made available their underemployment survey material and conducted a special follow-on survey at the request of the Committee; Mr. John Alden, Executive Secretary of the Engineering Manpower Commission, Engineers Joint Council, who gave the Committee an insight on the existing engineering data base and its shortcoming; Mr. Neal Rosenthal, of the Bureau of Labor Statistics, and especially Professor Seymour Wolfbein, whose professionalism brought the work of the Committee into final form; and Mr. Robert R. Hume who did the final editing of the report.

B. O. EVANS, *Chairman*
Committee on Engineering
Manpower Policy

Summary

The United States recently experienced a serious decline in the utilization of its engineering, scientific, and technical personnel. The beginning of the decade of the 1970s saw a significant increase in the number of unemployed, which reached a total of more than 50,000. Unemployment was significantly higher among both recent graduates and older professionals, in defense- and space-related activities, and in highly concentrated areas of the country. These developments are indicative of a lack of success in utilizing our scientific and engineering manpower, which is surely one of our most vital national resources. And there are indications that very significant professional experience has been lost in the process, some perhaps permanently. Thus, in mid-1971, the National Academy of Engineering appointed a Committee on Engineering Manpower Policy to consider the short- and long-term issues concerning the utilization of our engineering and scientific personnel.

In recent years, unemployment in the United States reached a peak of approximately 6 percent, while average unemployment among scientists and engineers peaked at only 3 percent. Why, therefore, does unemployment or other underutilization of engineers and scientists warrant special attention? The answer lies in the proportional contri-

bution of these groups, among others, to the quality of life and economic growth of the nation—factors of direct concern to all its people. Studies have indicated that in numerous countries there are definite, positive cause-effect relationships between the number of engineers employed and per capita GNP. Furthermore, there is evidence that in most industries there is a multiplying effect in which the employment of a scientist or engineer typically generates the need for several additional positions.

Although the productivity numbers cover a wide range, there is some substantiating evidence that, across many industries, engineers and scientists, on the average, generate revenues from five to ten times their cost of salaries, travel and burden rates; thus the work of the engineer and scientist creates amplified employment and is essential to the maintenance and growth of the GNP.

Currently, there is a marked uptrend in overall employment. However, the challenge of changing national commitments, the continuing difficulties of recent graduates causing pessimistic forecasts about the ability to absorb future graduates, which in turn will negatively affect future enrollments, plus the uncertainty of the utilization of some proper currently employed engineers and scientists, continue to underscore the need for new policies and programs affecting utilization.

This Committee, therefore, has focused its attention on what it considers primary longer-term issues involved in developing processes and building institutions that will help to improve the utilization of engineers and scientists. A society such as ours, which is heavily dependent upon technological advancement and innovation, has to expect continuing high requirements for the skills and talents of engineers and scientists. How they are utilized is therefore a matter of highest priority for the country.

The effective utilization of engineers and scientists depends on a diverse and complex set of factors, including the overall state of the economy, the directions chosen for national policies and commitments, industrial practices related to their recruitment and employment, education, training and retraining efforts of colleges and universities, and the comportment of engineering and scientific personnel in relation to the workplace as individuals and as members of professional groups.

It is not the purpose of this report to catalog all the factors pertinent to the nation's technical manpower concerns, nor is it possible to discuss, analyze, and make appropriate recommendations even for most of them. Instead, we shall focus on major arenas in which action is required to improve the utilization of engineers and scientists and to mitigate and perhaps even overcome some of the kinds of imbalance that have characterized the past few years.

In this context, the Committee's conclusions and recommendations are, in summary, as follows:

I

This Committee believes strongly that engineering manpower is a critically valuable national resource, that most action to influence the supply of this resource takes a long time to elicit a significant response, and that under these circumstances planning is unsurpassingly important to assure provision of the required talents in the quantity and quality necessary when they are needed.

Good planning requires valid comprehensive data on current manpower trends, valid translations of policies and programs into their manpower implications, and valid models for forecasting manpower demand and supply.

This Committee's efforts to assess the prospects for the utilization of engineers and scientists were hampered by lack of accurate current statistical information. The relatively few data that are available are fragmentary, generated by *ad hoc* surveys made in response to sudden shifts in demand. The lack of information also retards efforts to assay future manpower demand/supply trends and limits the analysis of the effects of current and changing policies and programs on the utilization of engineers and scientists.

The Committee therefore recommends the following:

1. *Development of a systematic and timely accounting of the effective utilization of engineers, scientists, and related personnel.* The government should provide the leadership and it can be done at relatively low cost by better focusing and adding to the present statistics-collection apparatus of various governmental agencies. However, industry and professional societies should supply critical parts of this information, advise and counsel on formulating the concepts and techniques used in gathering the data, and conduct surveys designed to produce special data on the nature and conditions of employment in the field.

2. With this kind of firm statistical base, this Committee recommends *further development of the concepts, techniques, and analyti-*

cal methods needed for gauging the manpower consequences of both public and private sector programs in enough detail to permit their use in making judgments about alternative policies and programs, with due regard for their impact on the supply of personnel.

3. With these in hand, it should then become possible *to develop models that may help anticipate the effect of actions in the manpower field.* The Committee recognized that this kind of work is highly complex and is still at the beginning of its development, so that care must be taken not to undertake unachievable models. But the Committee recommends that sufficient resources be applied to improvement of the technique both technically and conceptually as the basis for more effective planning.

II

The provision of a valid system of information on current and expected developments in the manpower demand/supply situation among engineers and scientists is a necessary but not sufficient condition for adequate planning, which this Committee believes could lead to better utilization. The executive branch of the government must deliberately and methodically take into account the manpower consequences of its current actions as well as of the changes it proposes in its policies and programs, at both the executive and legislative levels.

President Nixon recognized the importance of this when he declared in his *Manpower Report* for 1972 that "Both the efficiency of our economy and the well-being of the country's workers will be served by a more systematic assessment of the manpower consequences of government policies and programs."

Yet, this Committee has found that there is no defined mechanism for meeting this requirement in a systematic manner for planning purposes. Nor is there some focal group at an appropriately high level in government charged with the responsibility for coordinating the required efforts.

The Committee therefore recommends:

4. *The direct and indirect manpower effects of government policies and programs should be made clear and regularly taken into account as part of the annual budgeting cycles of cabinet departments and major agencies.* These departments and agencies should be required to assess and report on the effect on manpower, generally, and

on engineering, scientific, and related personnel, in particular, of programs in their jurisdictions. *Some overall government group, moreover—perhaps the Office of Management and Budget—should begin to aggregate these assessments and develop methods for utilizing them in determining recommendations on government policies and programs.*

5. Furthermore, this Committee *makes special mention of the importance of this kind of review on a regular basis* not only for continuing programs, but particularly for proposed changes in national commitments and policies, *both at the executive and legislative levels, in which the impact on engineering and scientific personnel supply and demand would be taken into account before the proposed changes are put into effect.*

6. *In all these deliberations there should be an involvement of the engineering and scientific community,* contributing advice and counsel, based on their special experience and knowledge, and relaying and communicating expected changes in programs and policies as quickly as possible. On their side, industry, the academic community, and professional societies should organize themselves to make the best possible responses to these efforts.

7. Following through effectively on these policy and program assessments requires that the responsibility for bringing it all about should be charged to and coordinated by some focal group. This Committee *recommends that this responsibility and the leadership for implementing government efforts to improve the utilization of engineering and scientific personnel be assigned to a central point such as the Executive Office of the President,* where it can be integrated with other elements of evolving national policy.

III

The United States is a technologically based society, and it needs now and for the future a longer-term strategy for developing a continuing high and relatively stable level of research, development, exploration, and innovation, particularly in the technologically more advanced sectors of the nation.

Such a strategy would help in improving the utilization of the engineer and scientist as well as other personnel associated with these activities in government itself, in industry, and in universities.

Attraction and retention of educated manpower and talent in a profession depends upon career prospects and reasonable security and stability. Steps must be taken to mitigate the effects of interruptions to employment when they do occur and to provide for mobility of these personnel as a matter of national interest as well as a service to industry and the industrial engineer and scientist.

The Committee therefore recommends:

8. *The government, again in consultation with industry and professional society groups, should set in place a plan for research, development, and exploration from the perspective of long-range national goals.* A specific objective should be to achieve high and stable enough levels of activity to reflect the needs of our society, particularly for innovation and technological advance. The achievement of this objective would support an improvement in the utilization of engineers and scientists as well as related personnel engaged in these activities.

9. Engineers and scientists are prominent among those whose stock of knowledge may become outdated under conditions of almost continuous and very rapid change. This Committee *recommends improvement in programs of industry, educational institutions, and government that will enable engineers and scientists to re-enter formal education and training when needed throughout their careers.* Much more information is needed, however, to determine the characteristics of programs that will succeed. Professional societies should take the lead in developing comprehensive and continuing information on the specific educational needs for industry, educational institutions, and the government.

10. Whenever unemployment does occur, a critical transition period takes place while, as other personnel do, engineers and scientists search for alternative places of employment. To permit such adjustments under conditions of minimal economic stringency, this Committee finds that there are many means for improving the adequacy of incomes during transition periods, such as provisions for termination benefits and vesting and portability of pensions, which would enhance the mobility of engineers and scientists. We also find that there are sound actuarial techniques for improving supplementary unemployment insurance benefits, which also exist in other sectors of the economy. *The professional societies should take the lead in analyzing termination and unemployment benefits and vesting practices, pointing out inequities, investigating alternatives, and recommending industry standards.*

And the professional societies should also investigate alternatives and coordinate development of improved unemployment insurance benefits.

ONE

Background

For the engineer, scientist, and technician, as indeed for many other professional personnel in America, the economic and industrial climate of the first years of the 1970s stands in sharp contrast to that which prevailed a decade earlier.

Ten years ago, this country was at the threshold of a huge commitment to defense and space, while experiencing a population increase generated by the advance of post-World War II birth rates and an uptrend in what turned out to be a significant expansion in economic growth. More recently, of course, there have been significant and often sharp alterations in our national policies, involving a large reduction in defense and space efforts, while population growth ebbed and the economy experienced a slowdown.

I

Just about every index of change documents these shifts—in the aggregate, by economic sector and industry and occupation, and by geography.

• Overall, federal research and development (R&D) funding, which *rose* at an annual rate of 5 percent in constant dollars during the period 1963–1967, was reversed completely and *fell* at an annual rate of 6 percent between 1967 and 1971.

▫ Industry, which always has been the major R&D performer, has seen its share of the declining total fall in turn from about 66 percent in 1963 to a little over 50 percent currently.

▫ As a brief example of geographic change, California's share of total federal R&D funding has fallen from 35 percent in 1963 to a little over 20 percent currently.

• Between 1968 and 1971, defense-related employment in the private sector declined by more than 1 million.

▫ Just three industry groups—aircraft, ordnance, and electronic components—accounted for about a third of this decline generated by the reduction in military expenditures by the Department of Defense (DOD). The three, which comprise the aerospace sector, employ about 15 percent of their work force as engineers, which is about double the percentage of engineers in other industries, such as electrical equipment, or in colleges and universities.

▫ In just the 2-year span 1968–1970, there occurred a reduction in civilian employment attributable to defense expenditures of 10 percent among natural scientists, 12 percent among technicians, and 13 percent among engineers.

• And the skills of these groups do not simply shift from industry to industry as national directions change for there are impeding education and skill mismatches, but, more important, there are striking differences in industry requirements. Construction and distribution industries, for example, use less than one tenth of the engineering and scientific resource per unit of output in comparison to that used by the transportation and aerospace industries.

Perhaps the most discernible, overt manifestation of these changes was the rise in rate of unemployment among engineers, scientists, and related personnel. As we will indicate later on, data on the employment status of these groups are fragmentary, but a special survey conducted by the Engineers Joint Council under the aegis of the National Science Foundation in August 1971 does provide some insight into the problem by revealing the following information:

• Under the official government definition of unemployment as representing all those with no work but actively seeking employment, a total between 50,000 and 60,000 engineers and scientists were unemployed. The majority of these were engineers. The unemployment rate for engineers stood at 3 percent in mid-1971, about double the corresponding rate of a year earlier and six times as high as that which prevailed in the latter part of 1968.

• Excluded from this definition were engineers employed in jobs well below their skill levels and those working part time, i.e., the underemployment. Underutilization is difficult to quantify; however, the Engineers Joint Council did estimate that the inclusion of engineers employed part time in engineering but seeking full-time work as well as those employed in nonengineering work would add another 1.7 percentage points to the official 3 percent figure.

• Disaggregating the overall unemployment rate of 3 percent yields significant additional information:

▫ Although the rise in unemployment among engineers between 1971 and 1972 was about double that which occurred for the labor force as a whole, some of the patterns of joblessness were quite comparable between the two. As is true for all groups, unemployment varied with educational attainment (4.4 percent for those with less than a baccalaureate and 1.9 percent for those with the doctorate). Holders of the doctorate were by no means immune from problems, as indicated by the fact that many were moving from industry into postdoctoral positions in universities, while others were holding lower-level college research and teaching assistantships formerly filled by graduate students.

▫ Similarly, and in line with the experience of others in the labor force, unemployment was highest for the youngest groups (5.5 percent for those under 25 years of age) falling to a low 2.2 percent for those in their late thirties and then gradually increasing with increasing age. This phenomenon, of course, indicates the existence of problems associated with age beyond the effects of a general downturn in demand. The fact that about one out of every four unemployed engineers had been managers (usually older) supports this conclusion. Very much to this point are data from a NASA survey made available to this Committee that showed unemployed engineers, scientists, and related personnel over 40 years of age having a very difficult time finding re-employment and even not staying in the profession.

▫ Reflecting the differential impact of recent developments in the engineering field was the fact that the highest rates of unemployment were experienced by aerospace and electronics industry engineers (tied at 5.3 percent). Toward the lower side of the spectrum were those in petroleum, environmental/sanitary, and civil engineering. Significantly above the overall rate of 3 percent were also those in systems and manufacturing engineering.

▫ On a geographic basis, and again in line with expectations, the highest rate of unemployment among engineers was recorded in Seattle, Washington (9 percent), and various areas of southern California as well as Cape Kennedy.

The unemployment data cited so far are from a cross-section survey pertaining to a single period of time and do not reveal some of the dynamics of change among those who were displaced. Useful insights along these lines were made available from an unpublished study by TRW Systems, Inc., of Redondo Beach, California, based on the responses from half of the 900 professionals who were laid off during the first months of 1970 and who had averaged 41 years of age, a weekly salary of $310, and 5 years of service.

• About 20 percent were able to find other employment in aerospace, and 30 percent found jobs outside that industry.

• Approximately 25 percent of the engineers and scientists involved accepted nonengineering jobs.

• About 70 percent of the respondents who did find work had been unemployed for less than 3 months.

▫ 44 percent were unemployed for less than 1 month.

• Sectors such as insurance, real estate, finance, and sales were the easy-to-find places of new job opportunity, but the respondents were neither professionally utilized nor satisfied with these positions.

Another study, this one by T. D. Brown ("An Analysis of Reemployment and Unemployment of Engineers Laid off from NASA Aerospace Contracts between June of 1968 and October of 1970") confirmed the major patterns uncovered in the NSF–Engineers Joint Council Unemployment Survey:

- Engineers 55 years of age and over who had been laid off experienced a rate of unemployment of 45 percent; those in the age bracket of 25–34, on the other hand, had a jobless rate of well under half of that–19 percent.

- Unemployment among laidoff engineers with master's degrees (at 21 percent) was considerably below that of those without a baccalaureate (33 percent).

- Engineers laid off in California had a rate of unemployment 4 percent above those laid off in southeastern United States and 13 percent higher than engineers laid off elsewhere in the country.

- Of particular significance was the fact that more than one out of every four (27 percent) of these engineers was still unemployed as of the spring of 1971.
  - Of those who were re-employed, only 53 percent were re-employed as engineers.
  - About three fourths of those re-employed did not get back to the aerospace industry.

- However, by mid-1971, a telephone follow-up survey indicated that the unemployment rate of 27 percent prevailing in the spring had declined to 4 percent.

Additional details are found in Tables 1–6.* For instance, in Table 1, the unemployment rate quadrupled to a level equal to that of all professional and technical personnel whose unemployment rate had doubled over the same period of time. For both groups, the jobless rates were still about half of what prevailed for the labor force as a whole.

The shift from space and defense activities (Table 2) generated significant differentials in the impact of unemployment among various engineering fields. In addition (as shown in Tables 3 and 4), differen-

**SOURCE:* Adapted from *Monthly Labor Review* "Characteristics of Jobless Engineers." 95(10):16–21, 1972.

tial unemployment rates prevailed among various geographic areas. Significant variations in the impact of unemployment are evidenced by age (Table 5) and educational attainment (Table 6)—two additional aspects related to the unemployment problem.

In the interpretation of these data it is recognized that possibly substantial numbers of unemployed "engineers" were engineers in name only, not qualified either by formal education or demonstrated professional accomplishment. Possibly many of these individuals were technicians with a rather narrow point of view, perhaps expert in a particular task but lacking in the breadth of knowledge and educational background necessary for the retraining or education contemplated for engineers. The appropriate identification of its practitioners in terms of minimum qualifications is an important issue for the engineering profession.

TABLE 1 Employment and Unemployment, 1967-1971

Group	1967	1968	1969	1970	1971
Engineers					
Employed	1,161	1,193	1,220	1,183	1,163
Unemployed	8	8	10	27	34
Unemployment rate	0.7	0.7	0.8	2.2	2.9
Professional and technical personnel					
Employed	9,879	10,325	10,769	11,140	11,071
Unemployed	133	126	144	227	333
Unemployment rate	1.3	1.2	1.3	2.0	2.9
All workers					
Employed	74,373	75,921	77,902	78,627	79,119
Unemployed	2,977	2,816	2,832	4,088	4,994
Unemployment rate	3.8	3.6	3.5	4.9	5.9

TABLE 2 Engineering Employment and Unemployment, Mid-1971

	Employment	Unemployment Rate	Percent of Total Unemployment
Total	1,100,000	3.0	100
Aerospace	60,000	5.3	12
Electrical	235,000	3.7	20
Mechanical	220,000	2.8	9
Chemical	50,000	1.9	2
Civil	185,000	1.2	4
All others	350,000	–	53

TABLE 3 Unemployed Engineers by Selected States, Mid-1971

State	Unemploy-ment Rate	Percent of All Unemploy-ment Reported	Percent in Survey Universe	Percent of All Engineers Employed in Private Industry
Washington	7.3	5	2	2
California	5.3	25	14	16
New York	3.2	10	9	12
Connecticut	4.4	4	2	3
Massachusetts	4.3	6	4	4
Florida	4.1	3	3	2
New Jersey	3.4	6	5	5

TABLE 4 Unemployed Engineers by Selected Areas, Mid-1971

	Unemployment Rates	
Area	Engineers	All Workers
Seattle, Washington	9.0	14.1
Orange County, California	7.4	7.4
Wichita, Kansas	7.1	10.7
Los Angeles–Long Beach, California	6.6	7.5
Cape Kennedy, Florida	6.6	–
San Diego, California	5.8	6.2
Boston, Massachusetts	4.5	6.2
Philadelphia, Pennsylvania	3.8	6.2
New York, New York	3.7	5.1
San Jose, California	3.5	6.5
Dallas–Fort Worth, Texas	3.0	–
Huntsville, Alabama	2.7	5.2
St. Louis, Missouri	2.2	6.4
Atlanta, Georgia	1.5	3.7

TABLE 5 Unemployment among Engineers by Age, Mid-1971

Age	Unemployment Rate	Percent of All Unemployed
Total	3.0	100
Under 25	5.5	4
25–29	3.3	12
30–34	2.2	10
35–39	2.2	10
40–44	2.7	14
45–49	2.8	16
50–54	3.3	14
55–59	4.1	11
60–64	4.2	6
65+	3.4	2
Not reported	2.4	1

TABLE 6 Unemployment among Engineers by Degree Level, Mid-1971

Degree Level	Unemployment Rate	Percent of All Unemployed
Total	3.0	100
Less than bachelor	4.4	16
Bachelor	2.8	51
Master	3.2	26
Ph.D.	1.9	5

II

The turn of events over the decade is illustrated by the following two comments:

The first, written in 1962 by the President's Science Advisory Committee, held that

> The impending shortages of talent, highly trained scientists and engineers threaten the successful fulfillment of vital national commitments. Unless remedial action is taken promptly, future needs for superior engineers, mathematicians, and physical scientists will seriously outstrip the supply.

The second, appearing in the April 28, 1972, issue of *Science* under the heading, "Job Market Rallies a Bit for June Graduates," pointed out the following concerning newly graduated engineers and scientists:

> Students who three years ago could have had several would-be employers in industry dangling now find themselves in the unpleasant position of being dangled. Companies that in the late 1960s would make several offers per opening to accommodate a high rejection rate are now making offers one by one, demanding a fast decision, and then moving on, if necessary, to the next candidate.

As this report is written, there is evidence of an improving situation, although unemployment still prevails among many engineers and the job market for new graduates is still a difficult one.

On an overall basis, economic growth and employment have improved, marked particularly by an increase of more than 2 million in total employment during the past year. Federal R&D funding turned around again and rose by more than 4 percent (in constant dollars) in fiscal year 1971 and projected trends for succeeding years show continued increases. By the middle of 1972 the unemployment rate among engineers had fallen back to about 2 percent. Those who were still unemployed tended to be in the salary bracket under $15,000, older (37 percent were over 50 years of age), and with lower educational attainment (half did not have a baccalaureate).

For the longer term, an impending oversupply of engineers and scientists up to and including holders of the doctorate has been projected through the next decade by both private experts and government agencies. Yet, in its most recent outlook statements, the U.S. Department of Labor in the 1972 *Manpower Report* begins by indicating that, "If any prediction about the employment future can be made with assurance, it is that professional and technical employment will experience renewed growth over the next decade at a rate considerably more rapid than employment generally." On the assumption of prevailing full employment in 1980, it then projects about a 40 percent increase in engineering employment during the current decade (1970 to 1980), which would approximately match the upcoming supply during the same period of time.

The department properly points out the many pitfalls that lie ahead for any projection of this sort, ranging from the very assumption of a peacetime, full-employment economy for 1980 to potential changes in the ebb and flow of engineering graduates during the 10-year span and indicates, in fact, that "If the shift away from engineering education should continue—under the influence of the current job-market situation—the numbers of new graduates entering the profession could fall below those required to meet expected long-run needs for engineers, thus hampering future efforts to solve the country's urgent problems and speed economic growth" (p. 107). It goes on to say that "It should be emphasized, however, that a neat balance between supply and demand in any one year would be fortuitous" (p. 124) and also underscores the findings of the National Science Foundation that point to a considerable oversupply of engineering doctorates by 1980.

III

This brief background description of the crisis attending the employment situation among engineers, scientists, and technicians at the beginning of the 1970s and the questions about the prognosis for the rest of the decade, reflect the lack of success in utilizing a key sector of our trained manpower, particularly as a resource in attaining national goals. This lack of success extends to other professional personnel, as well as other sectors of the American work force. The special importance of engineers, scientists, and related personnel is emphasized in the 1972 *Manpower Report of the President*, to which we already have referred as follows:

> Improvement of employment opportunities for engineers, scientists, and other professional personnel has an importance which goes beyond the easing of economic hardship for the individuals involved. This country had a heavy investment in the education of its professional workers, and an underutilization of their talents and training represents a national loss. The welfare of the nation, the quality of its life, and its protection within and without rest more heavily on the relatively small number of professional personnel than on any other occupational group. Thus, the future supply of professional workers and how this will compare with foreseeable needs are matters of national importance as great as or greater than current problems of underutilization.

In line with this statement, this Committee recognizes the fact that predictions and projections, forecasts and outlook statements on manpower demand and supply can prove to be wrong even in more closed and highly planned societies. This is so if only because of the indeterminate effects of such exogenous forces as changes in the international economic and political situation on the demand side, or the feedback effect from changes in supply generated by shifts in university enrollments and graduations elicited by those very assessments of the future.

The focus of this Committee, therefore, is not on the arithmetic of current and anticipated manpower demand-and-supply equations. It is, rather, on the more pervasive, underlying fact that a technologically based society such as ours has to look forward to continuing and extensive needs, quantitatively as well as qualitatively, for the hands, skills, and talents of engineers and scientists, their specialized knowledge, their ability to evaluate alternative policies and programs and their key positions in our academic, industrial, and defense programs, in maintaining a flow of capital goods, for conducting research and development of new products and processes, and for exploring new frontiers of natural resources and the conservation of our environment.

In this sense, the utilization of such personnel as scientists and engineers becomes a matter of primary rank nationally.

TWO

Building a Base

The effective utilization of engineers and scientists depends on a diverse and complex set of factors, including the overall state of the economy, the directions chosen for national policies and commitments, industrial practices related to their recruitment and employment, education, training and retraining efforts of colleges and universities, and the comportment of engineering and scientific personnel in relation to the workplace as individuals and as members of professional groups.

It is not the purpose of this report to catalog all the factors pertinent to the nation's technical manpower concerns, nor is it possible to discuss, analyze, and make appropriate recommendations even for most of them. Instead, we shall focus on major arenas in which action is required to improve the utilization of engineers and scientists and to mitigate and perhaps even overcome some of the kinds of imbalance that have characterized the past few years.

I

The first of these, which is the subject of this section of our report, concerns the need for a broad-based and sustained effort enabling government, industry, educational institutions, and individuals to participate in a more rational and systematic planning and policy-formulation program and action-development process than now exists.

This Committee believes strongly that engineering manpower is a critically valuable national resource, that most action to influence the supply of this resource takes a long time to elicit a significant response, and that under these circumstances planning is unsurpassingly important to assure provision of the required talents in the quantity and quality necessary when they are needed.

Planning has to be undertaken by every group affecting the engineer and scientist:

- The *educator*, as the trainer of the engineers of the future for the jobs they will do in the future.
- The *individual*, particularly the student, who ultimately makes the choice of career, and eventually becomes a member of influential professional groups.
- The *government*, as the largest single consumer of engineering manpower, not only influences the demand side of the equation but also may affect supply through a variety of incentives, including direct subsidy for training. Its actions in choosing among various alternatives in national policies also have a significant bearing upon the utilization of engineers and scientists.
- *Industry*, similarly, takes many actions that directly affect the supply, demand, and utilization of engineering talent in the marketplace and in the workplace.

In summary, then, we believe that good planning by all these groups is essential if our society is to be served effectively by its pool of engineering talent.

The ingredients of good planning are:

- Valid data on current manpower trends.
- Valid translations of policies and programs into their manpower implications.
- Valid models for forecasting manpower demand and supply.

Another way of saying this is that good planning needs:

- A firm information base on the employment, unemployment, and utilization of engineering manpower of adequate substance and technical reliability, provided in a timely, periodic, systematic fashion consonant in concept and technique with other economic data on the rest of the labor force.

• A systematic current program of research and analysis that makes it possible to uncover the employment–unemployment–utilization consequences of current and projected actions not only of the government but also of industry.

• The preparation of economic models that, by using these materials, might begin to make available good forecasts of the demand–supply situation among engineers and related personnel.

This Committee finds that we have a very long way to go in building this kind of solid base for planning programs and policies that will be responsive to the needs.

• The United States now has statistics on employment, hours of work and earnings, job vacancies, and related information, available monthly, in considerable industrial and geographical detail. The data are based on information supplied from industrial payrolls. Very few of these data, however, provide any information on professional personnel in general or engineers, scientists, and associated personnel in particular, since they are concerned with industrial rather than occupational detail, and they relate predominantly to the hourly rated worker below the supervisory level.

• A new program recently begun by the Bureau of Labor Statistics, however, will soon supply occupational data, classified by industry and geography, that should make it possible to see in better perspective the developments in professional fields including engineering in the context of trends for the rest of the employed work force.

• As for unemployment and utilization, no such developments are in prospect, and the outlook is for a continuation of what has gone on up to now, i.e., the mounting of episodic *ad hoc* surveys in response to needs created by current crises, which are abandoned as the crises pass.

This Committee recommends that a systematic, current accounting of the employment–unemployment situation among engineering and related personnel be undertaken. As a base, this accounting should provide data on such important variables as age, specialty, education, geographic location, and mobility of the personnel involved. In the interest of efficiency and economy, the government should provide *the leadership and start by orienting and supplementing its present surveys for the work force as a whole. Industry and professional societies would have a role in this undertaking, first, by supplying important parts of the information, second, by serving in an advisory capacity in helping to formulate the nature and conditions of the activity, and, third, by conducting their own special studies, particularly in the more difficult assessments relating to utilization and mobility experience.*

This Committee believes that the implementation of this recommendation is not only a *sina qua non* for intelligent planning and policy and program development but that it would produce a body of inherently useful substantive information. As a continuing data base it would be integral for appraising the manpower consequences of government and industrial action and the development of economic models. It would also serve as a source for an early alert to developments affecting the status of engineering personnel.

II

In his 1972 *Manpower Report*, President Nixon declared that:

> There is hardly any major aspect of government policy which does not significantly affect the utilization, size and skills of the country's labor force. Yet, during the 1960s, efforts to appraise the employment impact of new and changing policies and programs were fragmentary, at best—leading to avoidable inefficiencies in program operations and unnecessarily severe adjustments for workers, industries, and local communities. Both the efficiency of our economy and the well-being of the country's workers will be served by a more systematic assessment of the manpower consequences of government policies and programs. Accordingly, I am instructing the Secretary of Labor to develop for my consideration recommendations with respect to the most effective mechanisms for achieving such an assessment and for assuring the findings receive appropriate attention in the government's decision-making process.

This declaration represents a clear recognition that effective planning and action programs must be based on effective assessments of the manpower consequences of those very plans and programs—a matter that was overtly recognized by the Secretary of Labor, to whom the President's directive was addressed, in the following statement made in May 1972 before an industry–engineering society conference:

One of the things we learned from the recent and current aerospace unemployment situation is that we must never again institute drastic changes in national priorities without also considering effects on manpower. It may surprise you that we didn't do it this time. In some ways it surprises me—But one thing was certain. We did realize engineers constituted a tremendous national resource which the nation should not waste. And I think we also learned that we must, in the future, couple measures with priority changes.

A beginning has been made in this matter by both government and private organizations. In fact, the statistical information, presented earlier in this report, on the recent cutbacks in defense expenditures in industrial and occupational terms was based on some of this work. Pursuant to the President's manpower message, the Labor Department is supporting additional work in developing a relevant occupation–industry matrix based on input–output techniques that should be helpful in this regard. Some of the major users of engineering and scientific talent, such as the DOD and NASA, are also paying additional attention to these matters.

As anyone who has tried to evaluate programs (including government contracts to industry) in manpower terms even at a plant level knows, this is by no means a simple exercise. In fact, it is a matter of considerable conceptual and technical complexity, especially if one takes into consideration alternative manpower consequences of policies and programs of different size, composition, and goals. Of course, such translations gain in value exponentially when they also encompass such details as specialty, geography, age, and educational level.

A very considerable amount of research, development, and analysis, therefore, is still needed in order to assess and assay confidently the effects on the demand and utilization elements of this problem. We also point to the current lack of knowledge of the nature and timing of the process that links scientific and technological advance and the market opportunities and enhanced demand for engineering and scientific personnel they may generate. Yet knowledge of this process could be crucial in any attempt to estimate, say, the results of the multibillion dollar R&D effort in this country in terms of its manpower impact, particularly as we move more and more into the nondefense sectors of the economy.

As Dr. Harvey Brooks indicated in his 1971 testimony before the House Committee on Science and Astronautics, the task was not always easy and expeditious in forgoing the link between R&D effort and its utilization even during wartime. Brooks also has made the point that a better understanding of what did eventuate and how it was accomplished might give us perception on doing a better job in relating present R&D processes to future domestic nondefense market uses.

Specifically, he has said that*:

> I believe that the inability of private firms to recapture the benefits of R&D related to societal problems, is the greatest single cause of our present mismatch, and that substantial government investments will be required to create an effective demand, especially within the next five years or so, after which we may gradually learn how to create a quasi-private market for many of these services. One way this might be done is to tap the large cash flows associated with various activities in the private sector.

The extent to which the private industrial sector commits resources to assessing the effect of technological advance on the demand for the peacetime market may prove crucial to the size and composition of manpower requirements for engineers and scientists for the rest of this decade. A commitment to research and analysis of the process and its possible effect on the job market for the 1970s should be given high priority.

A good deal of effort is needed on the supply side as well, particularly in keeping track of the trends in university enrollments and the effect on them of government programs. A July 1972 National Science Foundation study on this matter began with the statement that:

> The general expectation of a continuing large expansion in the number of graduate programs, particularly in the sciences, of a few years ago, now appears unfounded. A recently completed survey indicates that little expansion in graduate programs in science and engineering occurred in the past 2 years, and even less is expected in the next 2 years.

Is it possible that the feedback effect from information on current job market and NSF's own forecast of a potential surplus of doctorates is already in effect? Yet, this very same report (Table 1) indicates that while the 1970–1972 period saw an increase of less than one (0.5) new engineering doctorate programs for every 100 university departments in that field, the projections for the 1972–1974 biennium show an increase to almost two (1.8) new engineering doctorate programs for every 100 university departments.

*Hearing before the Subcommittee on Science, Research and Development of the Committee on Science and Astronautics. U.S. House of Representatives, 92nd Congress, 1st Session. Washington, D.C.: U.S. Government Printing Office, 1971.

In this connection, Richard Freeman proposes in October 1971 in his "Science Manpower Market in the 1970s" that the key factor is the time required to educate engineers and scientists, which means that supply responds to past economic conditions and therefore lags far behind current demand. He says that:

> When demand is especially great and salaries are high, large numbers of students choose scientific careers; they graduate four to five years later and enter the job market, with a consequently depressing effect on salaries and employment opportunities. The result is a cyclic "cobweb" adjustment process, with periods of relatively great demand and high salaries followed by periods of relatively great supply and low salaries. Econometric calculations provide strong support for this interpretation of the market, at least in post-war years.

This Committee, therefore, recommends that a systematic, continuous program be developed that will begin to provide the necessary concepts, techniques, and analytical methods for analyzing the effect of public- and private-sector programs on manpower. The goal should be to include in such assessments enough occupational, industrial, geographic, and related detail so that the resulting materials can be used to provide guidelines for alternative policies and programs. The various factors that affect both the size and composition of manpower demand should be exposed, and, given the expectations for the rest of the 1970s, a substantial investment should be made in exploring the effects of technological advance on the marketplace and the effects of this on the demand for personnel. The supply side, of course, warrants similar attention, particularly on university enrollments.

III

A considerable volume of material projecting manpower demand and supply among engineers and scientists already exists. Much of this is produced by the government and some of it is relayed into guidance and counseling channels for use in career decision making. The total volume of this material has increased in the past few years, produced not only by government but also by private agencies and societies and academic experts.

These materials are based on increasingly sophisticated investigative and analytical techniques and have been considerably improved in recent years. However, certain difficulties and shortcomings still frustrate the efforts in this field:

• Insufficient good basic data on current developments in the manpower demand/supply situation among engineering and scientific personnel. We already have made recommendations on this matter.

• So far, most of the projections into the future have been based on extrapolations of past social, economic, and political trends. As the Labor Department's Bureau of Labor Statistics points out in commenting on its work in projections for professional manpower, "In general, these assumptions indicate that the long-term trends in the basic factors underlying the growth and changing characteristics of employment will continue." Specifically, the Bureau has used the following assumptions in looking ahead to 1980:

- The institutional framework of the economy will not change radically through the 1970s.
- There will be full employment in 1980, with an unemployment rate of 3 to 4 percent.
- The international climate will be improved. The United States will no longer be fighting a war, but the still guarded relationship between major powers will permit no major arms reduction. Defense spending, however, will be reduced from the peak levels of the Vietnam conflict.
- Armed force strength will return to approximately pre-Vietnam level.
- Economic, social, technical, and scientific trends will continue, including values placed on work, education, income, and leisure.
- Fiscal and monetary policies and an active manpower program will achieve a satisfactory balance between low unemployment rates and relative price stability without reducing the long-term economic growth rate.
- All levels of government will unite to meet a wide variety of domestic requirements, but Congress will channel more funds to state and local governments.

• If this is what actually ensues, then the Bureau's projections will indeed be generally correct, as they actually have been more often than not in the past quarter of a century. And the agency is careful to qualify its work by noting that "In any given year over the projection period the economy may be off this long term trend because of a war, recession, or other far-reaching exogenous factors."

• There is much to be said, however, for preparing projections that challenge the assumption of a basic stability in long-term trends, if only for illustrative purposes and for at least exposing the potentialities of such changes on future manpower demand and supply conditions.

- An interesting example of this kind of challenge appeared recently in *Science*, calling into question Allan Cartter's pessimistic assessment of the future for college graduates, calling his projections "Predicated on the general assumption that structural conditions within the society—notably within the political, economic, and educational realms—will continue essentially unchanged over the next two decades." The authors point to the emergence to a majority position of the service side of the American economy, the continued social pressures for professionalism of many occupations in that sector, trends toward more leisure time and the like and see all of this generating quite a different outlook from what Cartter has projected. Without making any judgment about who is "right," if indeed any appraisal of that sort could be made, the value of the exercise lies, at least, in its unsettling proposition of the potentialities of a changing environment.

- Over and above all these substantive and technical considerations lies the fact that there still does not exist an adequate theoretical construct that can serve as a basis for models utilizing empirical data and yielding forecasts that can in turn serve as a basis for developing strategies for action in this field.

- Models that postulate various conditions of the labor market related to alternative levels and rates of change in demand, and the responses effected through the behavior of the supply, may yield some new perceptions about the effects of various social and economic changes on future employment.

This Committee, recognizing that the development of models that will help in an understanding of manpower problems and in predicting the results of actions in the manpower field are an important aspect of planning for such personnel as engineers and scientists, recommends that resources be applied to their improvement both technically and conceptually, and that the government take the leadership in assigning responsibility and affecting a coordinated effort to implement this recommendation.

THREE

Toward Effective Planning

The Committee points out that the recommendations it has made so far in the past section do not warrant the construction of a new, complex, and expensive system of research, data collection, and analysis, because a substantial part of the necessary system already exists. Many parts of it have been operating in government for a long time and were, in fact, deliberately built for the sole purpose of gathering statistical intelligence. These include an established reporting system based on information from industrial payrolls that constitutes a significant volume of material monthly, nationally, by state, and by local labor market areas. Labor force employment and unemployment statistics with substantial demographic classifications also come out monthly from household surveys. A large number of data emanate from the programmatic responsibilites of such agencies as NSF and the Office of Education, and operating departments such as NASA and DOD also collect substantial amounts of relevant information.

The required information on the job fields covered in this report can be obtained at relatively small marginal cost by adding to the present system, including regularly scheduled special surveys from time to time, a procedure that has been used to obtain all sorts of needed data for many years. Some of this already has been begun.

But although the federal government and many private agencies collect and analyze data about engineering and scientific manpower, there exists no defined mechanism to put them into a common framework for analysis and to make the data and analyses available to all who might require them for purposes of forecasting and planning. Neither is there any defined mechanism for collecting and pooling data from nongovernmental sectors.

The need for a central focus, for a coordinated overview, for some organization to pull the strings together stems from much more than the need to marshal our research and statistical resources to bear upon the issues confronting the engineer and scientist in America. The need extends much more deeply to the development of a unified, well-integrated planning and policy- and program-development effort deliberately aimed at perfecting our utilization of engineering and scientific talent.

In this context, the federal government has for a long time been able to influence national manpower demand and supply in important ways. Other sectors of the society—such as industries and colleges and universities—also play critical roles, to which this report will address itself later on.

At this point in time, four aspects of the need for a systematic and continuous planning and assessment warrant special attention, and we now turn to these with a brief discussion and recommendation concerning each.

I

The effect of federal government policy can be very specific on both manpower demand and supply. On the supply side, the effect of national policy can be seen in actions varying from our broad immigration policy to specific programs aimed at specific occupational groups. Historically, the nation's basic labor supply came to us under a long-term open-door policy toward immigrants; it was curtailed sharply in 1921 legislation and was overhauled in 1965 legislation, which was quite relevant to matters being discussed here in the emphasis it placed on professional personnel whose admissions were liberalized; it was significantly limited again in 1970, by administrative action, to occupational categories in short supply.

The government's actions in education and training also go back a long time in our history, in fact back to the eighteenth century Northwest Ordinance, to the middle of the nineteenth century legislation setting up our land-grant colleges, to the middle of the twentieth century and the National Defense Education Act and its subsequent modifications, which up to this time are providing funds for students in a variety of undergraduate and graduate programs. By the academic year 1967–1968, one out of every five graduate students in engineering and science held a federally financed traineeship or fellowship; moreover, another one in five received support by federal financed research help. Since then, of course, a significant drop has occurred in this kind of support.

Federal action that attempts to affect supply, therefore, has been characterized not only by a broad range of policies and programs but also has been marked by significant turnarounds both in rate of change and in direction of change.

Much of the same has attended the effect of government action on the demand side, which, again, has ranged from broad-based, aggregative policies aimed at the overall employment picture through fiscal and monetary policy to specific programs affecting specific groups. Nowhere has this been more discernible in the past dozen years than in defense and space and related fields and among engineers, scientists, and associated personnel. Some of this impact already has been documented in our first section.

The 1972 *Manpower Report of the President* put much of this in a context by itself, noting that:

> The new focus on manpower revealed much that had previously been hidden or not fully understood. For instance, the country became aware of the long lead-times involved in the development of manpower. Children who fail to acquire basic skills in school are likely to be handicapped throughout their working lives. A decision to open a new medical school will result in a first graduating class a decade later. A decision to place a large contract in a small community may lead to boom in that town, which may be followed by heavy unemployment in a few years afterward if the level of Federal funding is cut back.
>
> The implications of this time factor are as simple as they are significant. The more a nation plans ahead and the more it takes into account the future implications of its actions, the more likely that it can expand opportunities.

Some other aspects of this phenomenon need specific mention at this point:

• Government policy in this field is by no means limited to the oft-mentioned defense–space–R&D spectrum of activities. Recent developments in health care and medical research, for example, have brought a huge burst of change in the manpower demand–supply relationships among professional personnel. Recent developments in policies and programs as varied as those impinging on agricultural supports, highways, and urban transportation also have affected the demand for professional personnel.

• By the same token, *all* sectors of employment have been affected. We already have noted, as an example, the effect of reduced defense expenditures on private industrial employment (a decline of a full million in the space of 2 years). Others have had similar experiences. At the beginning of the last decade (1960) the federal government's $300 million contribution represented one half of the total basic research effort of our universities. In half a dozen years that contribution rose to over $1 billion, and universities increased their engineering and scientific staffs, on a full-time equivalent basis, by more than 50 percent. In more recent years, of course, the trend has changed. The government itself is also a major employer of personnel. More than 1 million civilians were employed in defense-generated activities at all levels of government in 1970, a quarter of a million of them in professional and technical work.

• Particular attention must be paid to the effect of government action, whether or not it is defense-related, not only on the total numbers involved but just as importantly on different occupational groups and specialties as well as the location of employment. The varying effect of government expenditures for example, has been documented to show that, based on 1970 prices and employment patterns, $1 billion of expenditures on personal consumption would generate employment of 900 engineers. A similar allocation to construction would increase the employment of engineers more than a third to 1,250; employment of engineers would more than double to 2,000 if those expenditures went to the production of capital goods and would more than quintuple to 5,000 if the allocation went to aircraft or ordnance. The effect on changes in programs in various parts of the country already has been pointed out earlier.

• The side effects of a wide range and diversity of government programs also have to be taken into account. These can range from salary practices for government employees and their effect on rates and levels of pay in the industrial sector to the impact of investment tax credits. Thus, there is very little indeed in government action that does not have a manpower impact.

This Committee, recognizing both the direct and indirect effects on manpower of government policies and programs, recommends that these effects be made clear and taken into account as a regular function of the annual review and budgeting cycle of cabinet departments and major agencies. At a minimum, the agencies of government should provide themselves with the capability of assessing and reporting upon the impact on manpower, generally, and on engineering, scientific, and related personnel, in particular, of program developments in their jurisdictions. In this connection our recommendation in the previous section on developing the concepts and techniques for translating programs into their manpower terms is specifically relevant. This Committee further recommends that some high-level government-wide group, perhaps in the Office of Management and Budget, aggregate these assessments and take them into account in determining recommendations on government policies and programs.

II

The sustained regular assessment of the manpower implications of government policies and programs would be a historic and critical step toward more effective utilization of our manpower resources. This would be particularly so for engineers and scientists, for whom a long lead-time is necessary for a good demand–supply balance and for whom, therefore, the earliest alerts on change are necessary.

We want to call particular attention again to the great importance of assessing the manpower implications of programmed or expected *changes* in program and policy.

Commenting on the supply side of the equation, the Labor Department has pointed out that "The 1960s demonstrated that, over time, large-scale Federal expenditures tend to add to the supply of competent persons through on-the-job training and upgrading. This has been true in companies with defense and aerospace contracts, where large numbers of technicians were drawn up into the ranks of professional engineers and many professional workers added to their competence through additional education and experience. Subsequent declines in the demand for the output of these specialized companies have resulted in the displacement and underutilization of large numbers of able people in whose expertise the country has invested large sums." The Department then went on to point out how the manpower aspects of changes were neglected by noting that ". . . generous support for graduate education in science was continued even after the growth in Federal expenditures for research and development began to level off." And it concluded that "Major shifts in Federal policy, leading to large-scale expansion or contraction in the education or employment of scientific manpower, can reduce the effectiveness with which institutions of higher learning perform their tasks, as well as the research capabilities of major scientific centers and teams."*

Some of the most dramatic changes affecting the demand–supply situation among engineers and scientists are generated by federal legislation, and it is a rare occasion indeed when deliberations on significant legislation are accompanied by assessments of their manpower implications–an exercise that conceivably could affect the thrust and substance of the legislation being considered.

Within just the past year the Congress has considered legislation with potentially significant implications for professional personnel. Included are environmental pollution (the President's Council on Environmental Quality envisages the expenditure of more than $110 billion in the period 1970–1975 on air, water, and solid-waste pollution control), housing, urban transportation, and health.

This Committee therefore recommends that special attention be paid to the manpower consequences of anticipated changes in national commitments, policies, and programs, both at the executive and legislative levels, and their effect on engineering and scientific personnel supply and demand be deliberately considered and taken into account in making these changes.

III

In his first Message on Science and Technology on March 16, 1972, President Nixon noted that:

. . . we must appreciate that the progress we seek requires a new partnership in science and technology–one which brings together the Federal Government, private enterprise, State and local governments, and our universities and research centers in a coordinated effort to serve the national interest. Each member must play the role it can play best; each must respect and reinforce the unique capaci-

**Manpower Report of the President.* Washington, D.C.: U.S. Government Printing Office, 1972. Page 20.

ties of the other members. Only if this happens, only if our new partnership thrives, can we be sure that our scientific and technological resources will be used as effectively as possible in meeting our priority national needs.

The implications of the interactions suggested by the President are significant and substantial and have direct bearing on the problems affecting the utilization of scientific and technical talent and on the possibilities of success in dealing with those problems. The statement makes unmistakably clear the critical importance of effective communication among all the elements, institutions, and constituencies involved and thus is particularly relevant to the substance of this report.

It is obviously not sufficient for the government to engage in the work we have suggested if it (a) does not involve such institutions as industry, the academic community, and professional societies in the assessments of the manpower implications of policy and programs and if it (b) does not effectively communicate to them the results, the outlook, the portents, the alerts, the signals that these assessments produce.

Moreover, industry has a critical role in the communication effort. Through established organizations such as the Business Council, or through some new organization such as a Manpower Advisory Board (these are not mutually exclusive) it should be possible to deal on some regular basis with industry-wide manpower problems by bringing firms with various experiences together for analyzing and assessing manpower problems associated with national policy and programs. Individual firms have accumulated substantial manpower knowledge. Shared experiences directed toward common national problems could provide a basis not only for industry-wide solutions but also for relaying those experiences and suggested actions to the government. Industry should also have a voice in national manpower planning and assessments, should serve on the deliberative and advisory councils of government dealing with this general area, should make manpower recommendations for any contemplated changes in federal policy or proposed priority shifts affecting engineers and scientists, and should relay into their own systems and programs as quickly as possible the results of these national actions.

Similarly, educational institutions must serve in corresponding capacities. While education, of course, has a much broader function than the vocational preparation of professional and technical personnel, it has to take account the changing world of work and the changing levels of support for some of its major curricular components, as it has learned from the turn of events of the past few years. At the same time it must also help in designing a responsive reporting system of student choices and enrollments and completions to give us the needed intelligence on what is happening on the supply side. As we shall suggest later, it should also share in the work involved in the retraining of talent.

Finally, the professional societies, which historically have played an important role in the entire process, particularly in collecting and disseminating a wide variety of technical information as well as in helping to collect and analyze a good bit of the statistical data on manpower, represent an excellent forum both for imparting substantive knowledge and advice to the agencies involved in planning and for communicating as quickly as possible the manpower message that emanates from that planning.

This Committee therefore recommends that the government planning and assessment work that it has suggested up to now should involve closely the elements of the engineering and scientific community. The government should seek their advice and counsel, obtain the results of their knowledge and experience, and employ them as central pathways for communicating expected changes in programs and policies and their manpower effects. These various elements—particularly industry, the academic community, and professional societies—should in turn so organize themselves as to be able to act appropriately in relation to the government planning and assessment function and to communicate the results of their actions as effectively as possible on a continuing basis.

IV

Another condition is necessary for the most effective possible implementation of this Committee's recommendations. A focal group at an appropriately high level in the federal government should be charged with coordinating the required efforts among the various constituencies in and out of government that are involved. Its charge should also include assuring that the utilization of engineering and scientific talent receives the attention it warrants in consideration of the manpower effects of alternative economic policies on the American labor force as a whole.

There are important analogies in both the private and the public sector. Very few, if any, industrial firms would consider putting consideration of their production management, policy, and operational concerns anywhere but at the highest level of corporate structure, testifying to the importance assigned to this fundamental part of an establishment's life. In following this practice there is no diminution of the importance of the efforts of the individual divisions or plants in the corporate structure which also have key responsibilities in this domain.

The same procedural principle applies to the education–employment–unemployment–utilization problems of the engineer and scientist and associated personnel. The basic job in research, statistical collection and analysis, program review, and manpower assessment will exist in individual federal agencies that, as many do now, will have interagency arrangements bringing the results of their work into some shared experience and review.

This Committee recommends that the leadership for implementing governmental efforts to improve the utilization of professional, engineering, and scientific personnel be assigned to a central point such as the Executive Office of the President in order that evolving national policy, commitments, and programs take into account the impact on a critically important national human resource.

FOUR

Improving Utilization

So far we have been discussing processes and institutional arrangements relating to the utilization of engineers and scientists. In this final section, our concern will be the engineers and scientists themselves, their relationships to the workplace, and the forces that affect the manner in which their talents are utilized.

The following statement from the 1972 *Manpower Report of the President* emphasizes one of the major forces relating to utilization problems among engineering and scientific personnel and is in line with the leverage exerted by federal government expenditures:

> Manpower shifts in Federal policy, leading to large-scale expansion or contraction in the education or employment of scientific manpower, can reduce the effectiveness with which institutions of higher learning perform their tasks, as well as the research capabilities of major scientific centers and teams. To the maximum extent consistent with other national objectives, Federal funding of scientific research should be guided by a long run strategy which will give adequate protection to the training capabilities of the country's major educational institutions and to the maintenance of a competent cadre and a broad-based research structure. At the least it should avoid or minimize sudden shifts which may result in later shortfalls in scientific manpower or in the erosion of the research capability required for national defense and social and economic progress.

Some kind of long-term strategy that would be based on a continuing, high, and relatively stable level of funding of research, development, and exploration, particularly in the technologically advanced sectors of the nation, would have major portents for the country and the economy as a whole. The United States is a heavily technologically based society and it requires now and will need for the future a continuing and dependable innovation function.

This Committee's view of the need for this longer-term strategy is analogous to the view we have taken previously in this report concerning the manpower supply–demand situation among engineering and scientific personnel. We are not so much concerned with the specifics of the expenditures involved as we are with the need for a long-term look, with appropriate planning and program development, that will help assure technological innovation and advance. The outlook for the 1970s, with the additional emphasis on research and development on such public problems as transportation, urban development, health care, energy, ecology, and all the rest enhances the appropriateness of this view.

Such a strategy would also help, of course, in improving the utilization not only of the engineer and scientist, but also of other personnel at different occupational levels who are associated with these kinds of activities in government itself, in industry, and in the universities. These expenditures are part of the pattern of the more general fiscal and monetary efforts of the federal government seeking to support economic growth and expanding levels of employment for an expanding labor force expected to reach a total of 100 million by 1980. This fact underlies the recommendation of this Committee suggesting some agency at an appropriately high level of government to integrate the utilization of engineering and scientific personnel with considerations concerning economic and employment trends in general by such agencies as the Council of Economic Advisors.

One other factor in this connection deserves special mention. In many aspects of government expenditures, including defense and space, major geographic considerations are involved. The 1972 *Manpower Report* quoted above also points out that "The fact that many contractors and subcontractors are concentrated in a limited number of locations implies intensified repercussions on local and regional economies in periods of either rapidly increasing or rapidly declining Federal expenditures" (p. 14). The data on the effect of recent events on the geographic dimensions of employment and unemployment among engineers already have been documented in our first section.

The geography of employment, in general, or for a very specific group of workers in a very specific sector (whether it be engineers in aerospace or welders in shipbuilding) has for a long time posed many social, economic, and political issues. This was illustrated in a dramatic manner when the President of the United States brought the news to two Long Island counties, previously considered part of the New York City complex, that they were now to constitute their own standard metropolitan statistical area, permitting them to exhibit their higher, separately calculated unemployment rate, which, in turn, might enable them to bid on government contracts from a more advantageous position.

Careful consideration of the geographic concentration in some federally supported activities in the planning of those activities might mitigate the sharp effects on various local areas caused by changes in government programs, particularly with the advice and counsel of the industrial and professional sectors involved.

This Committee, therefore, finds it appropriate that the government, in consultation with representative groups from industry and professional societies, set in place a long-term strategy for implementing this country's research, development, exploration, and associated activities in consonance with national goals. The specific goal should be the achievement of both levels and rates of change consonant with needs for technological innovation and advance for both domestic and international purposes. This should become part of the general design of government programs for achieving employment growth with stability.

II

In presenting its recommendations and findings, this Committee has viewed the engineer and scientist in relation to the labor force as a whole. The events of the past quarter of a century have repeatedly underscored the fact that the educational system of this country must provide the means for keeping the labor force up to date, to make up for deficiencies in the first round of learning relating to new developments and, of course, to keep up with the rapidly expanding bodies of new knowledge. Furthermore, within the last decade it has become well recognized that, within the life of an individual engineer, it is entirely possible that the need can develop for re-education in preparation for virtually an entirely new engineering career.

These needs apply to the engineer and scientist with particularly compelling force. Among other difficulties is that of the re-employment of displaced personnel in the older age groups. A study completed 6 years ago found that in 39 technologically oriented firms the problem of skill obsolescence was most damaging among persons 35 years and older engaged in research and development or in design functions. A more recent survey of 2,500 design and development engineers confirmed the close association of obsolescence with age.

The latter study also found that current practices carried on for continuing education did not result in preventing or even remedying obsolescence of skills, even among companies that allocated considerable resources to these programs, and laid the blame on the inadequacy of short-term part-time courses as a means of enabling engineers to keep up with new technological developments.

We do not at the present time have enough information on what constitutes successful training and retraining programs. This kind of information must be collected and transmitted to industry, academic institutions, professional societies, and other groups involved in training and education.

Skill obsolescence as it relates to age is due to become even more serious as the average age of technically trained manpower goes up in the years immediately ahead, reflecting the increase over the past 20 years in the number of new entrants into engineering and scientific fields.

The rate of technological change has been so fast that serious gaps have been created in the armament of skill and knowledge that engineers and scientists bring to bear on their jobs. From every viewpoint—society's, industry's, and that of the personnel themselves—this puts in jeopardy the considerable investment made in that talent and all have a stake in preventing that kind of erosion.

Industry in particular has applied a large variety of methods to refurbish and update the engineer's and scientist's skills and knowledge, ranging from company training programs, company-financed study at universities in graduate curricula, or special seminars and programs to attendance at technical and professional meetings.

This Committee has noted the recent increase in recommendations for the provision of more extensive periods of study for engineers and scientists in industry comparable to what is available to university personnel, e.g., sabbatical leaves on full or partial salary depending on the length of time of the leave. Activities during sabbatical leave would follow various pathways, including formal educational courses or participation in research projects.

However, no matter what the exact form of process is adopted, it is unequivocally clear that the classic lockstep sequence prevailing for so long, in which a period of education was followed by work that, in turn, was then followed by retirement, does not correspond to the realities of our technological environment or the realities of the job market, or indeed to the needs of the individual engineer and scientist. "Continuous education," "recurrent education," "within-career education," and similar terms all point in the same direction, namely, to the need for developing means by which technical personnel at all levels can keep up to date in their respective fields during their entire working lives.

As more and more employing institutions, both public and private, adopt means of implementing this idea, educational institutions must gear themselves to provide needed learning opportunities on a degree or nondegree basis, with the required substance and timing. There has been a substantial growth in college and university activities of this kind, but as a 1969 National Science Foundation study of continuing education among R&D engineers and scientists indicated (NSF 69–70) we still have a long way to go in this regard.

The NSF study, which involved personnel in a selected group of large industrial and government laboratories, found that "In general, the academic people interviewed stress the point that the schools' primary functions are to provide training for students seeking degrees and to generate new knowledge through research. At the present time, these two functions have priority over continuing education."*

As a matter of fact, half of the universities interviewed in the NSF study did *not* provide short intensive courses, in-lab courses, seminars and symposia, and the like for engineers and scientists wishing to engage in updating and refreshing their knowledge. The report indicates that "Among the 12 'inactive' schools, the decision not to engage in continuing education programs has literally been made by the faculty jointly through discussion. The reason for the decision is to avoid diluting the main effort of teaching and research" (p. 153).

There is, of course, at least one other stage at which an education–training–retraining component could make a significant contribution, i.e., when an engineer or scientist becomes unemployed. This idea has, in fact, received a good deal of recent legislative attention. Thus H. R. 15789 (National Science Policy and Priorities Act of 1972) called for, among other things, authority for NSF to award career-transition fel-

***Continuing Education for R&D Careers.* Washington, D.C.: National Science Foundation, 1969 (NSF 69-70). Page 151.

lowships in educational programs to facilitate the re-employment of engineers and scientists; S 1805 (Peacetime Conversion Assistance Act) would also provide training assistance and S 1191 (Peacetime Transition Act of 1971) also carried provisions for job retraining.

This Committee also has noted the efforts of the Technology Mobilization and Reemployment Program (TMRP) carried on since the spring of 1971 by the Labor Department at the specific direction of the President. The program includes a range of services for engineers, scientists, and technicians displaced from aerospace and defense-related jobs, including job-search and relocation grants as well as support for training and retraining. It has been carried on in close cooperation with the major professional societies and, interestingly, uses the services of unemployed personnel in carrying out some of the programs. Not all the returns are in on TMRP, but the most recent information available at this writing shows some success in skill-conversion efforts among displaced engineers and scientists. Approximately 3,200 of these personnel were provided with either on-the-job or academic training or a combination of both prerequisites to firm job offers by employers.

For most members of the American labor force and particularly for such technology-related personnel as engineers and scientists, there is a documented need for substantive pathways that will enable them to update their stock of skill and knowledge. We see no diminution in that need in the years ahead.

This Committee, therefore, recommends continued improvement in opportunities for engineers, scientists, and related personnel to continue their education and training throughout their careers. Complementary activities are needed by (a) industry supportive of sustained periods of refurbishing of skills and knowledge by their staffs, (b) educational institutions making available curricula and faculty needed to support this kind of activity, and (c) government, in cooperation with the relevant industry and professional society groups, supporting retraining opportunites for displaced personnel. In all cases, much more information is needed on what constitutes a successful continuing education or training program, and this information needs to be collected and fed back to all the groups that take part in supporting and carrying out these programs. We recommend that professional societies take the lead in developing comprehensive and continuing information on the specific educational needs of engineers and scientists for industry, educational institutions, and government.

III

As we have said, shifts in national priorities can generate what is perhaps the most extreme form of malutilization of engineers and scientists, i.e., unemployment. We have explored a variety of suggestions for dealing with this phenomenon, including, for example, instituting shorter work weeks as a temporary response to changes in activity and geographical headcount ceilings on government contracts. We have found, however, that, while reducing hours of work in order to maintain staff may be feasible in a given plant to cope with short-run disequilibria, or limiting the contractual coverage of a geographical area may avoid extraordinary local consequences, these are not appropriate as a matter of national policy as long-term solutions.

Most efforts to deal with unemployment seek first what can be done to prevent the occurrence of that phenomenon, and many of our recommendations, such as those concerning planning and the maintenance of a high and stable level of research, development, and exploration, are pointed in that direction. The attractiveness of a profession for educated personnel depends on reasonable stability of employment, which also is a primary determinant in effecting better utilization of the professional person.

A second objective involves policies and programs to keep the duration of joblessness as brief as possible, again as an example, the government's TMRP program to which we have referred, which includes job-search help, mobility assistance, and the like, emphasizes this point.

A third objective involves supplying some kind of income to those who are unemployed until they find employment again, a matter not only of obvious significance to the engineer or scientist himself, but also to the economy of an area to the extent that it mitigates sharp fluctuations in consumer expenditures and mitigates sharp drains on area unemployment and welfare reserves.

This third objective is basic to the philosophy underlying the general system of unemployment insurance that prevails in most parts of the world. The unemployed engineer and scientist is part of that system through contributions made to the unemployment insurance funds by industry under the federal–state system in effect today.

The unemployment insurance system in this country is now more than a third of a century old. More than four fifths of all workers are now covered; the duration of time a person is eligible to draw benefits while unemployed, while averaging about half a year, has been extended to 39 weeks under certain conditions by recent legislation; and unemployed workers can receive as much as about two thirds of their weekly pay in the form of benefits.

There has been a considerable amount of discussion of the need to improve the status of the unemployed, including engineers and scientists, beyond the basic provisions of the unemployment insurance system during the hopefully relatively brief transition period between jobs. There has been a plethora of suggestions for bringing this about. These range from government subsidization of any increased cost of such plans, particularly in the case of changes in defense and space contracts, to a wide variety of strictly private-sector plans—some on an industry-wide basis, some custom-tailored to the needs of individual enterprise.

There exist today some analogues in the private sector in a number of industries, including autos, steel, and others, in which plans have been negotiated calling for a system of supplementary unemployment benefits on top of the regular unemployment insurance system. These tend to be employer-financed and can result, of course, in a substantial increase in overall benefits to unemployed persons.

This Committee has explored the feasibility of designing a sound, actuarially based, jointly financed system of supplementary unemployment insurance for engineers under the aegis of individual companies or professional societies. Specific recommendations for carrying this out are beyond the scope of this report. We have found, however, that properly designed (and there is a considerable body of actuarial and related experience available to help in such a proper design) a system aimed at providing more adequate income during periods of joblessness would seem to be a worthwhile goal to pursue. It would enable engineers and scientists, as it is already enabling other parts of the American work force, to make a shift to other jobs under mitigated conditions of financial pressure, whenever the need arises.

The matter of shifting employment and career patterns brings up another point for consideration. Professional personnel always have exhibited higher rates of migration and mobility than other groups in the labor force, and engineers and scientists are no exception. They move among sectors, government–industry–education, and geographically and industrially in response to a variety of influences, particularly to changing patterns of demand.

Improvement in mobility is a worthwhile goal from many points of view; however, there is a barrier to mobility of engineers and scientists that warrants attention and consideration of possible solution.

A matter of great concern here is the widespread lack of transferability among company pension plans, which can operate as a deterrent to job transfer especially for older employees. The absence of vesting provisions, which means that the man who leaves a firm or is laid off must leave without the employer's portion of his pension accrual, may pose severe financial problems at retirement time. This is exacerbated by the absence of portability, i.e., the inability of an employee to transfer the equity built up in the retirement plan of one employer to the retirement plan of a new employer, whether the change is generated by a voluntary shift of jobs or by layoff.

A variety of legislative proposals relating to this problem during the last session of the Congress and the recent discussions concerning the establishment of national plans by engineering and scientific professional societies reflect general national concern. Indeed, the professional societies within the last 2 years have demonstrated an increasing concern for the economic well-being of their members and have taken commendable initiative in the development of appropriate programs as a result. As promising as the results of this interest have been, substantially more action is needed in this broad area.

Again, there are analogues in many sectors of the American economy, including industry-wide pension plans, within the federal government establishment and in a substantial part of the academic community that indicate that a viable system might be established for removing this deterrent to mobility of the engineer and scientist.

This Committee, therefore, finds that in the general context of evolving programs for the labor force as a whole, there is considerable room for enhancement in the economic status and mobility experience of the engineer and scientist. This applies particularly to programs that would serve to improve the adequacy of their incomes during periods of transition between jobs and that would provide continuity through vesting and portability in their pension plans. We recommend that the professional societies take the lead in analyzing termination and unemployment benefits and vesting practices, pointing out inequities, investigating alternatives, and recommending industry standards. And the professional societies should also investigate alternatives and coordinate development of improved unemployment insurance benefits.

Bibliography

1. Data on the recent unemployment experience among engineers and scientists can be found in *Unemployed Rates for Engineers, 1971* published by the National Science Foundation (September 23, 1971) and *Employment Problems of Engineers Highlighted by New Survey* from the Engineers Joint Council (September 24, 1971). These data are also detailed and analyzed in the *Monthly Labor Review* for October 1972 (Vol. 95, No. 10) in "Characteristics of Jobless Engineers," p. 16–21.
2. Information on changing levels of defense expenditures in general and research and development in particular and their impact on utilization of engineers and scientists is presented in the National Science Foundation's *Science Resources Studies Highlights* (NSF 72-314, August 11, 1972; NSF 72-311, July 21, 1972; NSF 72-318, December 13, 1972). Cf. also "Employment Effects of Reduced Defense Spending" and "Occupational Impact of Defense Expenditures" in the December 1971 issue of the *Monthly Labor Review.*
3. The job outlook for engineers and scientists is discussed in Cartter, Allan M., "Scientific Manpower for 1970–85" in *Science*, 9 April 1971; Wolfle, Dale, and C. V. Kidd, "The Future Market for Ph.Ds." *Science*, 27 August 1971; National Science Foundation, *1969 and 1980 Science and Engineering Doctorate Supply and Utilization*, NSF 71-20 (May 1971); "Professional Manpower: The Job Market Turnaround," *Monthly Labor Review*, Vol. 95, No. 10 (October 1972), p. 9–15; U.S. Department of Labor, Bureau of Labor Statistics, *Occupational Outlook Handbook*, Washington, D.C., Government Printing Office, 1972; Freeman, R. B. *The Science Manpower Market in the 1970s*, National Science Foundation, October 1971; T. R. Vaughan and

G. Sjoberg "The Politics of Projections: A Critique of Cartter's Analysis," *Science*, Vol. 177 (1972), p. 142–147.

4. The need for continuing education among engineers and scientists is discussed in P. H. Mangum and A. W. Warner's *Obsolescence and Updating of Engineers' and Scientists' Skills*, New York, Columbia University Press, 1966; Dalton, G. W., and Thompson, P. H., "Accelerating Obsolescence of Older Engineers," *Harvard Business Review*, September–October 1971; *Continuing Education for R&D Careers*, Washington, D.C., National Science Foundation, 1969 (NSF 69-70).
5. *Manpower Report of the President* for 1972 contains an extensive discussion of many of the forces affecting the utilization of engineers and scientists, particularly in Chapter 5, "Manpower Issues in the Professions and Higher Education."