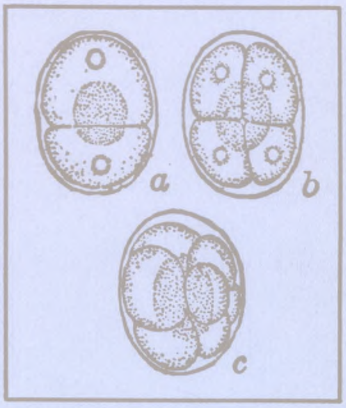
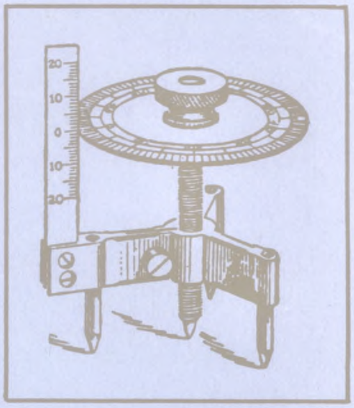
Federal Spending and Scientist and Engineer Employment

BULLETIN 1663

U.S. DEPARTMENT OF LABOR
Bureau of Labor Statistics

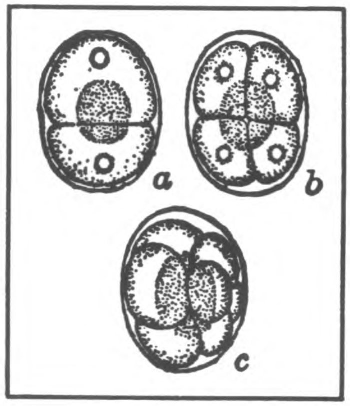
1970

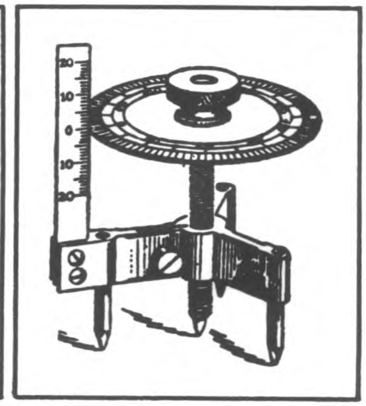




Federal Spending and Scientist and Engineer Employment

A Study in Measurement





BULLETIN 1663

U.S. DEPARTMENT OF LABOR
J. D. Hodgson, Secretary

BUREAU OF LABOR STATISTICS
Geoffrey H. Moore, Commissioner

1970

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Preface

Recognizing the need for an assessment of Federal Government expenditures on the demand for scientific and technical personnel, the National Science Foundation provided financial support to the Bureau of Labor Statistics (BLS) to study methods of measuring this effect. BLS hired Dr. Robert L. Aronson to carry out the study during his leave of absence from the School of Industrial and Labor Relations, Cornell University. Dr. Aronson was encouraged to express his professional judgment in carrying out the study. Therefore, points of view or opinions stated in this report do not necessarily reflect official opinions of either the Department of Labor or the National Science Foundation.

The number of persons in various public and private organizations who provided assistance or counsel to Dr. Aronson during this study is too large to identify in all cases. For their help, special mention is acknowledged to Roger W. Jones, Michael March, and Carey P. Modlin, all of the U.S. Bureau of the Budget; Murray Weidenbaum, formerly of the Department of Economics, Washington University; Allen O. Gamble, National Institutes of Health; Leonard Lecht, Center for Priority Analysis, National Planning Association; and Paul Downing, U.S. Department of Defense. Various members of the staff of BLS provided technical assistance, including Neal H. Rosenthal, Michael F. Crowley, and Daniel E. Hecker, of the Division of Manpower and Occupational Outlook; Thomas Fleming and Richard P. Oliver, of the Division of Economic Growth; and Douglas Schmude and Edith Andrews, of the Division of Occupational Employment Statistics.

Robert Cain and Norman Seltzer of the Sponsored Surveys and Studies Section, National Science Foundation, were instrumental in shaping the goals and direction of the study and in providing general counsel and assistance.

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FEDERAL SPENDING AND SCIENTIST AND ENGINEER EMPLOYMENT

Chapter I. Introduction and Highlights

Relatively large amounts of information on scientific and technical manpower in the United States have been collected for nearly two decades. In terms of the numbers employed, the industries and institutions involved in their employment, the sources of supply, the nature and character of their work, their education, training and mobility, perhaps no other group of occupations has been subjected to as much continuous and detailed observation. Curiously, however, the apparent richness of the sources of data has not been accompanied by a substantial body of research directed to increased understanding of the employment and utilization of scientific and technical manpower.

The influence of the Federal Government on the employment of scientific and technical manpower deserves more than the casual speculation it has thus far received, because of the degree in which the Government uses scientific and technical knowledge in its programs; and has generated substantial social and economic interest because of its policy implications.

The kinds of scientific and engineering talents engaged in Government-supported programs may have a major, if not preponderant, influence on technological development and innovation. The technological choices made by scientists and engineers may have intended costs as well as benefits that reach well beyond their immediate frames of reference. From the economic viewpoint, awareness is also growing that scientific and technical manpower devoted to one set of uses, such as Federal programs of research and development, implies the sacrifice of other socially useful opportunities for their employment. In the absence of a market mechanism for rationing this scarce manpower resource, as is typically the case in public programs, other means of evaluating its deployment will need to be developed.

The study objectives focus on a single question: How useful are the available sources of data on scientific and technical manpower for measuring the effects of Federal programs on employment of scientists and engineers?

Some data sources already include source of support as an explicit dimension, but the occupational, character of work, and institutional coverage of these sources is incomplete or inadequate from an analytic viewpoint. Consequently, the principal effort of the study became directed principally towards deriving approximate measures of Federal influence on the employment of scientists and engineers, especially in respect to those dimensions not presently covered by survey design.

A major conclusion of this study is that existing sources of data on Federal expenditures and on scientific and technical manpower can provide useful results in measuring the program—employment relationship. The results obtained, however, represent only broad and approximate relationships. For manpower planning in connection with Federal programs data that are more detailed, more precise, and more compatible with a variety of analytic measures of activity, will be required.

For the most part neither the sources of data nor the methods used in this study to test their measurement capability are novel. Expenditures per man-year and input-output analysis have been used as complementary means of estimating employment attributable to Federal spending. Since the latter approach converts industrial and occupational coefficients of employment into estimates of numbers employed, only the expenditure data used in this approach were unavailable through official publications. All other estimates were derived from published sources.

The resulting estimates of federally supported employment relate either to 1965 or 1966. At the time at which the study was made it was not possible to obtain employment and expenditure data which would permit measurement of the government's influence to a comparable extent for later years. In addition to the lapse of time between survey dates and the availability of the data, certain essential employment and financial data are collected independently on different time schedules. Comparison of two different approaches to measurement, based on independent sources of data, further restricted the timeliness of the employment estimates. Recommendations which could lead to more timely estimates are made in the concluding chapter of this report.

Conceptual problems in measuring the Government's effect on the employment of scientists and engineers and the sources and nature of available manpower and expenditure data are discussed in chapter II. Estimates of federally supported employment in the extramural sectors are developed and evaluated in chapters III and IV. Direct employment in the Federal Government itself is the subject of chapter V. Chapter VI brings together the results of the three preceding chapters, illustrates some applications of the resulting estimates of employment, and offers recommendations for changes in the concepts and procedures for collecting data on the employment and utilization of scientific and technical manpower.

Highlights

Exploration of the capability of data to estimate the effects of Federal programs on the employment of scientists and engineers yielded the following results and general conclusions:

About 393,000 scientists and engineers, or nearly 30 percent of the estimated total employed in 1965,[1] derived their employment from Federal funds. Only a third of this number were employed directly by the Federal Government.

The proportion of federally supported employment of scientists and engineers varied markedly. The relative numbers were estimated to be less than 20 percent in private industry and in State and local government, but were as much as 40 percent of scientist-engineer employment respectively, in universities and colleges and independent nonprofit organizations.

Federally supported employment of scientists and engineers is heavily concentrated in all sectors of research and development (R&D). Overall the Federal Government was estimated to employ about 55 percent of R&D scientists and engineers in 1965; only about 5 percent of non-R&D scientists and engineers were employed in Federal programs.

Defense and space programs in 1966 were estimated to employ nearly 80 percent of scientists and engineers in the extramural sectors. More than half of Government civilian scientists and engineers were also employed in those programs.

Federal employment of engineers in 1965–66 exceeded the employment of scientists. However, in terms of total scientist and engineer employment, a greater proportion of scientists than engineers were employed in Federal programs. Federal utilization was greatest in the life sciences.

Measures of federally supported employment developed in this study indicated that in the late 1950's and early 1960's annual increases in Federal program requirements equaled about 25 percent of the average annual number of bachelor's and first professional degrees conferred in the sciences and engineering.

The foregoing estimates of federally supported employment of scientists and engineers and some illustrative applications indicate that currently available data sources have a useful but limited capability for measuring the employment effects of Federal programs. However, the estimates of employment were possible only on the basis of rather broad assumptions about the relationship of employment and Federal expenditures.

Data on output and expenditure in Federal programs were found to be weaker than employeemnt data in most of the dimensions investigated.

The general strategy for developing data adequate for scientific and technical manpower planning in Federal programs should be improvement of existing data sources rather than development of a single integrated data system. Greater coordination and compatibility among the sources of employment and expenditure data, buttressed by periodic benchmark surveys of Federal involvement, should satisfy most needs for manpower planning in Government programs.

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[1] Latest data available at time of this study.

Chapter II. Government Programs and the Measurement of Manpower Requirements

The conceptual basis for measuring Federal requirements for scientific and technical manpower is essentially similar to the general basis of manpower measurement. The underlying concept of all such efforts is that a functional relationship exists between the output of goods and services and the numbers of workers employed. Where public goods and services are involved, technical and institutional factors may require some modification in the design of the information system used to capture and analyze the relationship between output and manpower. Elaboration of the foregoing statement as background to the efforts at measurement attempted in this study is the purpose of this chapter.

The concept of Federal manpower requirements

Governments use manpower for the same general purpose as other organizations and economic sectors —to produce goods and services. Just as in the general case, the Government sector has a production function relating the quantity of goods and services produced and the quantities of resources used, including the numbers of scientists and engineers. The production function for each uniquely identifiable output of goods or services, that is, a particular Government program, will differ from the production functions for other Government programs. Such functional relationships will also differ from those for other economic outputs, such as those purchased in the markets for private goods and services. Further, it is reasonable to assume that manpower requirements to serve Government programs are subject to dynamic influences more or less common to those occurring in other economic sectors. Technological change, changes in the supply and prices of cooperating factors of production, and changes in the composition of output resulting from changes in purchasers' preferences affect the supply of public as well as private goods.

The application of the concept of a production function to public programs, however, raises some special difficulties which affect the measurement of manpower requirements. First and foremost is the concept of output as applied to public goods and services. In a number of areas of Government activity, especially in the domain of the Federal Government, the output of public programs is objectively unmeasurable. The most obvious instance is the national defense and security. No apolitical means has been found for determining whether security from attack, or offensive capability, is increased or decreased by a particular level or mix of armaments and military manpower.[2] Similar difficulties of concept arise in other areas, although perhaps not to be same degree, such as in space exploration, the development of nuclear energy, and in the more traditional functions of Government such as education or the maintenance of internal law and order. In some other areas, such as transportation, the delivery of mail, and certain health services consumed directly, the concept of Government supply is both more easliy recognizable and quantifiable.

The difficulty posed in the foregoing is especially decisive in projecting the levels and changes in the levels of output and employment associated with public goods and services. Although far from completely adequate, the private sector experience tends to support the theory of a functional relationship between changes in expenditure, output, and employment. This relationship can be roughly determined from economic models relating the growth and composition of the labor force, productivity, rates of consumption and investment, and so on, to changes in gross national product and, especially, to changes in the demand for goods and services in particular industries. Such models often provide the means for determining manpower requirements, although they are usually implicit in manpower forecasts.[3] A functional model of the demand for Government output, on the other hand, has yet to be devised, largely because the factors that determine such a demand are mediated through a political mechanism. Except in a few cases involving Government enterprises, no market can be shown for Government output, and consequently no determinate relationship exists between the "price"

[2] The evaluation of the "quantity" of security depends on factors such as the military posture of other countries, the political situation, the availability of technical means, etc., as perceived by military and diplomatic intelligence and as interpreted by the executive and legislative branches of Government.

[3] For example see *The Long-Range Demand for Scientific and Technical Personnel,* National Science Foundation, (NSF, 61–65, 1961).

of such output, expenditure, and the quantities demanded. The absence of output measures also makes difficult forecasting whether or not changes in expenditure on Federal programs will result in corresponding changes in employment. An increase in expenditure in a program area may represent an increase in program activity or output. Unlike goods and services produced in the private sector, however, practical means of distinguishing increases in real output from rises in unit resource costs are rare in Government programs.

Two methods of dealing with this issue can in principle be devised. One is to develop quantifiable measures of program achievement, such as those contemplated as part of the Planning-Programming-Budgeting System (PPBS)[4] or in the recent National Planning Association study of the costs of social goals.[5] The other method is to deflate program expenditures of real resources used, such as manpower. The methods used in this study out of practical necessity are more closely related to the second possibility. As will be seen later, this study is based on the assumption that program expenditure equals program output; this measure has been related to employment by means of a common dollar denominator.

In approaching the measurement of manpower requirements for Federal programs as a practical problem, account must also be taken of the institutional and organizational complexities. The principal institutional fact is that the Federal Government operates in a so-called "pluralistic economy."[6] The Government engages in direct production of its output only to a limited extent, partly as a matter of tradition and partly as a matter of economic and political strategy. A substantial, if not a major part of its total output is achieved through employing other sectors, from which the Federal Government purchases goods and services, or to which it makes grants-in-aid, loans, or subsidies. Through these various financial arrangements, other economic sectors may be co-opted into Federal programs. Some or all of these other sectors also employ each other, through purchase or subcontract, in furthering their own participation in Federal programs. Thus, an important objective in measuring scientific and technical manpower requirements in Federal programs is to determine the sectoral distribution of these requirements.

The organizational structure and processes of Federal decisionmaking further complicate the treatment of the Government's manpower requirements as functional entities. The basic organizational structure for both appropriation and administration is departmental, but this arrangement does not necessarily coincide with distinctive functions and program goals. Competition among agencies for funds for similar, even identical purposes makes it difficult to determine the functional distribution of activity. The Planning-Programming-Budgeting System, gives promise of integrated program planning in the Federal Government, but for the near term future at least the assumption that Government programs represent a set of possibly overlapping production functions is often closer to reality.

The elements of a model

An information system for measuring manpower requirements in Federal programs should have two broad and related attributes in its design. First, it should supply the information necessary to its intended uses. Second, it should result in data that more or less accurately mirror the structure, processes and behavior of the organizational units covered. Although these two attributes jointly influence the design of the system, their respective influences are probably somewhat different. Purposes will have greater influence on the coverage of the system and the kinds of information collected, while the structural-functional character of the organizational units involved will tend to govern the concepts, classification schemes, and level of detail. The implications of the first of these attributes can be dealt with briefly, since they rest on the assumption of a production function and past experience with manpower information systems generally. The second attribute, on the other hand, deserves more extended consideration, since it involves novel and possibly more troublesome elements. Most of the discussion in this section consequently will be devoted to the structural and functional elements of Federal programs.

A manpower information system for Federal programs, focused either on scientists and engineers or on a broader range of occupations, could serve a variety of purposes. Such a system could: (1) Permit comparison among Federal programs in terms of the human resource and related physical requirements as a basis for funding; (2) permit evaluation in like terms of either new program activities or changes in existing program structures and support levels; (3) provide a basis for measurement and evaluation of the adequacy of current or future manpower resources to support

[4] For a clear account and analysis of the development and implications of PPBS, see Charles L. Schultze, *The Politics and Economics of Public Spending,* (Washington, D.C., Brookings Institution, 1968).

[5] Goals analysis is a relatively new field in which measures of output are largely determined from normative standards. See Leonard A. Techt, *Goals, Priorities and Dollars: The next Decade* (Free Press, New York, 1966); and *Manpower Requirements for National Objectives in the 1970's* (Center for Priority Analysis, National Planning Association, Washington, D.C., 1968), especially pp. 5–7.

[6] For an interesting definition of this term and discussion of its significance see Eli Ginsberg, Dale L. Hiestand, and Beatrice G. Reubens, *The Pluralistic Economy* (New York, McGraw-Hill, 1965).

current or projected Federal programs; (4) provide a basis for evaluating the influence of Federal manpower utilization on the deployment and compensation of all workers; or (5) permit tracing the flows of manpower resources used in Federal programs over time and among industries or large regions.

Not all of these purposes need be simultaneously satisfied, but they share certain common informational requirements. Information would be needed on program outputs, that is, the specific nature and quantity of the work in terms of program objectives, to the degree to which these can be quantified, and the current or expected total expenditures associated with the program activity. Insofar as scientists and engineers are concerned, uses (3), (4), and (5) would also require that the system be consistent—though not necessarily integrated—with a system of manpower information covering the non-Federal economic sectors.

The structural and functional attributes of a Federal program oriented system of manpower information may be more troublesome for several reasons. Some of the difficulties perceived here seem to derive from the "information complexities,"[7] inherent in the labor markets for scientists and engineers, but others may be unique to the nature and functions of the Federal Government and to the variety of ways in which it gets its work done. Federal programs vary greatly not only with regard to their respective objectives, but also—and more importantly with respect to manpower requirements—in terms of the means by which those objectives are served. A variety of organizational patterns in carrying on Federal programs must be accommodated in an information system. Finally, programs may vary with respect to their duration, from those with specific timebound objectives to those that are continuous and indefinite. Brief discussion of each of these aspects as a conceptual problem will help to appreciate the associated informational requirements. For the most part they provide the framework for a system of Federal manpower planning.

Federal spending covers a very broad and diverse spectrum of activities intended to serve purposes that have been jointly defined, approved and funded by the President and the Congress. The budget documents, for example the Budget for Fiscal 1969, classify outlays and expenditures on these activities in two principal ways: By administrative agency and by function. For either fiscal planning or analysis of past utilization of manpower resources, however, neither classification is ideal. Manpower requirements should be related to the end products to which they contribute, rather than to the channels of employment and financial flows. Since with few notable exceptions, Government programs involve the services of more than a single agency or bureau and a number of agencies are involved in more than one program, the administrative classification of either fiscal or manpower inputs would not be revealing of the input-output relationship. The functional classification scheme employed now for several years, exclusive of expenditures for general government and interest payments, is made up to 10 principal categories. Although it is a step in the desired direction, the classification still appears to be ex post the budgetary decisions rather than an operational basis for allocating financial or other resources.[8] Comparison of the expenditure totals for education given in the main budget document and in the special analyses reveals the ambiguity of the present scheme. For fiscal 1967, the total Federal outlay on education, including net lending, given in the functional classification of the budget was about $4.0 billion, but Federal expenditure on education in all programs in that period was $9.2 billion. The difference between these two concepts presumably is that the first relates to expenditure on education as a final output, while the second also includes educational expenditures as inputs in support of other objectives—defense, for example.[9] Conceivably, measurement of manpower requirements could be desired for either type of functional classification, and the information system should accordingly be flexible enough to accommodate both types.

The manpower information system also must comprehend structural differences among programs in the ways in which their objectives are met. In addition to civilian and military employees of the Federal Government, other program performers include industrial and nonprofit contractors, State and local governments both as contractors and recipients of loans and grants, and various other organizations and individuals who receive payments for goods or services. Each of these performer groups will generate varying employment

[7] The term is that of Allen O. Gamble whose discussion of the scientist-engineering manpower information system remains the leading work in this too sparse field. See his "Proposal for Development of An Improved Manpower-Related Information Program," *Toward Better Utilization of Scientific and Engineering Talent* (Washington, D.C. National Academy of Sciences, Committee of Utilization of Scientific and Engineering Manpower, 1964), pp. 106–107.

[8] See Joint Economic Committee, Subcommittee on Economic Statistics, The Federal Budget and/or Economic Document (Washington, D.C., 88th Cong., 1st Sess., Report No. 396, 1963), p. 9. Although some progress has been made toward a genuine program approach, the successes have been sporadic and mainly at the intra-agency level. See Joint Economic Committee, Subcommittee on Economy in Government, *The Planning Programming-Budgeting System: Progress and Potentials* (Washington, D.C., 90th Cong., 1st Sess., 1967).

[9] Whether this distinction is itself valid is questionable. In *The Budget for Fiscal Year 1969,* aid for undergraduate and graduate students in 1967 is shown as $421 million, but in *Special Analysis H,* the sum of undergraduate and graduate and professional student support is $925 million for that year. No clue in either of these parts of the Budget will explain this difference.

requirements for given levels of Federal expenditure, depending on the nature of the activity involved. This point may be simply illustrated by comparing the percentages of employment in the private sector directly attributable to Federal purchases of good and services, including the compensation of Government employees, in different programs, during the period 1962–66:

	All programs	*(percent) Defense—atomic energy*	*Nondefense and space*
1962	44.6	42.6	50.0
1963	46.4	41.3	61.9
1964	45.1	41.3	57.9
1965	43.2	40.3	52.6
1966	42.7	42.3	47.1

SOURCE: *Manpower Report of the President—April 1968,* appendix table G-4, p. 322.

Finally, the manpower information system must be able to discriminate between programs, or program elements, that are terminal and those that are continuous in duration. On the basis of recent experience, apparently the requirements for scientists and engineers vary with the phases of the program as well as with the levels of expenditure involved. Some fragmentary evidence of considerable variation may be found in studies of the development of the Titan II intercontinental ballistic missile and of a computerized Navy command and control system. In the latter case, for example, the engineering work force engaged on the project varied over a 6-year period from 8 to 16 percent of the total engineering force at the contract facility. Unfortunately, no data are given to indicate the changes in the total engineering complement, but the engineers employed on the computer contract increased more than sevenfold over the entire contract period.[10]

On the other hand, some activities of the Federal Government are open ended fiscal commitments, but with manpower coefficients that tend to be comparatively stable over time. Few such programs, however, currently are large users of scientific and technical manpower.

From this background it is now possible to indicate the components and characteristics of a manpower information system for Federal programs, focusing on scientific and technical occupations. This "model" is appropriately discussed under the following headings: (1) Program concepts, (2) program performers, (3) manpower and financial data, and (4) responsibility for data collection and frequency of reporting.

Program concepts. In general, the manpower information system should discriminate between groups of activities each of which represents a common objective or end result. The activities to be included in any given program category, therefore, should be determined by the contribution of the activity to the purpose of the program, and not by the similarity of specific functional characteristics. Thus, for example, employment on school construction designed to improve the quality or adequacy of public education should be classified as an element in an educational program rather than as a public works activity, even though it also might be undertaken to achieve the purpose of a public works program.

The classification of any given activity (or closely related set of activities), accordingly, cannot be established by treating it as an isolated phenomenon. Although each specific case of classification may present special problems of definition, a general test of where an activity belongs might be the response to the question of complementarity: Will the objectives or goals of the program be achieved in the absence of this particular activity? An affirmative answer, of course, implies either that the activity belongs in some other program category or is per se questionable as a Government program. Such a test does not preclude in the course of time changes in program activities, either because objectives are reformed in the light of changing conditions (including the effects of the programs) or because new techniques of achieving program objectives come to light. Indeed, one of the major objectives of a program classification is to facilitate rational analysis of such factors.

For analytical reasons, especially for assessing manpower requirements and evaluating performance, activities should be grouped into so-called "program elements." Bureau of the Budget guidelines for the Planning-Programming-Budgeting System[11] define a program element in terms of its characteristics—a "clearly definable output," an end product for the operating agency, rather than an intermediate product; and output varying, though not proportionally, with changes in inputs.[12]

Program performers. Public programs in the Federal Government are served in a variety of ways. A manpower information system should reflect and cover the different organizational forms involved, not only because of differences in the nature of their relationship to the Federal Government, but also because differences in cost, manpower utilization, and program effectiveness may be involved. Thus, the system should comprehend not only the leading Federal agencies

[10] Paul W. Cherington, "Case Studies of Titan II and NTDS," *Toward Better Utilization of Scientific and Engineering Talent: A Program for Action* (Washington, D.C., National Academy of Sciences, Committee on Utilization of Scientific and Engineering Manpower, 1964), pp. 127–128.

[11] *Planning-Programming-Budgeting: Bureau Guidelines of 1968* (U.S. Senate, Committee on Government Operations, 1968).

[12] Ibid.

directly involved in program management and operations, but also all other major units supplying inputs to the program: Businesses and industries, other Federal agencies, other governments, and nonprofit and educational institutions. In addition, because each of these organizations purchases inputs used to supply Federal program output, measurement of the manpower indirectly hired is also desirable.

Data requirements. The assumption is that data collected by a manpower information system will be used for analytical purposes; projection of occupational requirements for scientific and technical personnel may be the most important purpose. For this and most other conceivable uses, the minimum data requirements would include:[13]

1. Total program employment broken down by program element and by type of performer.
2. Scientists, engineers, and supporting technical personnel employed by each program element and corresponding performer, broken down by occupational specialty.
3. Information on (2) with respect to the functional or character-of-work assignment of the individuals employed.
4. Total expenditure or costs for each program element, distributed among personnel, equipment and facilities, materials, and overhead expenses.
5. A measure of the real output of the program element.

None of the above data requirements is free of difficulties of definition. Among the more troublesome is the question of occupational classification. Any such scheme, no matter how fine grained, is inherently arbitrary when measured against the adaptability of trained men and women to a variety of tasks. Even training in those scientific and technical fields which require long periods of formal education in particular disciplines and technologies has not been particularly restrictive when new tasks and requirements have emerged. The design of an occupational classification scheme that will fit the great variety of tasks performed by scientific and technical manpower clearly should have a high priority.

Administrative responsibility and frequency of reporting. Although congruence between program and organizational structures in the Federal Government is not necessary, for most of the existing program categories one agency is dominant, and administrative and operating responsibility probably is more concentrated at the program element level. Administration of a scientific and technical manpower information system similarly could be decentralized by following the dominant agency principle; the appropriate bureaus or divisions would be responsible for data collection and reporting within a common informational framework. Tabulation and analysis beyond the level of agency or particular program need, however, could be left to an organization with overall responsibility and interest in scientific and technical manpower resources.

Frequency of reporting depends on the use of the data, and may be affected by the nature of the program. Programs with substantial expenditure and manpower weights in the scientific and technical areas may require more frequent monitoring than those programs that use relatively little of such input. Likewise, programs with major short term fluctuations in requirements suggest the need for a greater frequency of reporting than programs that change more slowly and predictably. A mixed system of data reporting seems indicated. Comprehensive bench mark data could be collected on all programs at common reporting dates, and more frequently programs of selected interest and, probably, of major importance.

Data sources: expenditures and manpower

As an empirical matter, whether or not the effect of Federal programs on the employment of scientific and technical manpower can be measured depends on the nature of the data available. In the course of this study all of the major data sources were reviewed and their characteristics examined in terms of the needs outlined in the preceding section. None of these sources either jointly or as independent data systems, of course, completely satisfies the needs of an ideal system with the capability of measuring the manpower requirements of Federal programs. Some of the sources do address the issue of Federal influence directly, but others, as will be shown subsequently in chapters III, IV, and V may provide more meaningful results.

Discussion of data sources may conveniently be organized in the following categories: (1) Measures of program activity and output, (2) expenditure and costs, and (3) employment. Particular sources of data in some cases overlap these categories, so that repetition is unavoidable. Most of the sources are available in published form, although not all data collected in the established information programs are published.

Measures of program activity and output. Measures of program activity and output in the Federal Government are still in the early stage of development. However, the stimulus to this development given by President Johnson's August 1965 directive to install the Planning-Programming-Budgeting System on a Government-wide basis has resulted in some progress. *Special Analysis R, in the Budget, Fiscal Year 1970*[14] for the first time since the President's directive provides a review and analysis of the programs of 17 Federal

[13] These proposed data requirements lean heavily on the discussion by Gamble, op. cit.

[14] *Special Analyses, Budget of the United States, Fiscal Year 1970* (Washington, D.C., 1969) pp. 252–273.

agencies, covering about 95 percent of the proposed budget, in detailed terms.[15]

The data presented are in financial terms, although in some cases there is a statistical as well as a narrative account of the activities to be undertaken. In other parts of the 1970 budget, and also in the budgets for earlier years, program activities are presented for a smaller number of selected programs and agencies in terms of both outlays and services provided.[16]

Comprehensive measures of program output nevertheless are still poorly developed, and indeed for a number of federally supported programs the prospect of such measures seems remote. For Government as a whole, output in the national income accounts is expressed in value terms as roughly equal to the sum of the cost of employee services and the value of Government purchases of goods and services.[17] Because of the aggregation problem, progress toward *real* measures of total Government output is unlikely in the near future. In some particular agencies, however, efforts to measure physical output as a management tool for evaluating agency performance have begun. In addition to a limited experiment in selected agencies,[18] all of which confined the measure of input in the productivity equation to in-house employment, a few agencies regularly collect and tabulate data on their programs, which includes extramural employment as well as corresponding measures of output. The Atomic Energy Commission, for example, uses scientific publications as a partial measure of output in its Physical Research Program; the scientific man-years involved as well as the associated financial outlays are reported.[19] The Atomic Energy Commission, on a broader basis, also projects manpower requirements in the atomic energy field, mainly on the basis of expenditure plans and projections. Few other agencies as yet attempt such measures of program output, although progress is being made in the development of program memoranda for PPBS presentations. In research and development, where Federal support and utilization of scientific and technical manpower is heavily concentrated, general measures of output may be practically unattainable because of the problematic outcome of R&D effort.[20]

Expenditure and cost data. In the absence of adequate real measures of program output, data on expenditure must serve as a proxy in measuring manpower requirements. Indeed, this may be the only general basis for estimating employment attributable to Federal support, and extensive use has been made of financial data in this study. Such a basis, however, is beset by numerous risks in interpreting results, because of cost differences in the character of work, fields of science, and the practices of performing organizations. The greater the detail available, the more likely the manpower estimates will approximate reality.

Two general sources and several more specialized sources of financial data can be used in equations for estimating federally supported employment of scientists and engineers. The most general, of course, is the *Budget of the United States.* This document, which records both outlays and proposed expenditures, covers the total of Federal spending on a fiscal year basis. Expenditures are tabulated both by agency and by broad functions and program. A derivative and companion source to the Federal budget is the annual survey, *Federal Funds for Research, Development and Other Scientific Activities,* sponsored and conducted by the National Science Foundation. *Federal Funds* provides expenditure data on Federal support of research and development, R&D plant, the collection of scientific data, and the communication or storage of scientific information. R&D support data are broken down by character-of-work, fields of science, performer, and by sponsoring or administrative agency. In addition, for major features of Federal support each volume of *Federal Funds* contains historical series from 1952 onwards.

Although presently of limited use in estimating federally supported manpower requirements, data on Federal support to higher education is available in the CASE[21] series, which provides information on an institutional basis in support of academic science and nonscience activities. An expanded CASE program is expected to cover additional sponsoring agencies and to provide information on a project basis, including the utilization of manpower.

Expenditure and some cost data are available from National Science Foundation surveys of scientific and technological activity in four sectors—industry, universities and colleges, State Governments, and nonprofit institutions. The industry survey has been conducted annually since 1957, but surveys in the other three sectors have been irregular or less frequent. Two of the surveys—the surveys of the colleges and universities and of the nonprofit institutions—also provide considerable information on federally Funded Re-

[15] Ibid, p. 254.

[16] Ibid., p. 157. For example, hospital and medical services, for which the number of patients treated and the number of clinic and physician visits are indicated along with dollar outlays.

[17] See U.S. Department of Commerce, Office of Business Economics, *National Income,* 1954 edition (1954).

[18] *Measuring Productivity of Federal Government Organizations* (Office of the President, Bureau of the Budget, 1964); also, William A. Vogeley, *A Case Study in the Measurement of Government Output* (Rand Corp., 1958).

[19] *A Statistical Summary of the Physical Research Program* (U.S. Atomic Energy Commission, June 30, 1968).

[20] Nestor E. Terleckyj, *Research and Development: Its Growth and Composition* (New York, National Industrial Conference Board, 1963), pp. 11–12.

search and Development Centers administered by the institutions.

At to expenditure data useful for estimating federally supported employment of scientists and engineers, all four surveys publish data on the sources of support for research and development. Only two—the industry and the nonprofit institution surveys—provide specific estimates of man-year costs of scientists and engineers, however. All four surveys provide distributions of expenditure by field of science. Only one of the surveys—the university and college survey—includes some expenditure data on non-R&D activities in academic science fields.

Employment data. Development of employment data on scientific and technical manpower has been extremely prolific, possibly exceeding that of any other specialized occupational group. In the course of this study more than 14 sources were investigated.[22] Eight of the surveys include specific information on federally supported employment. Some, as in the case of the NSF sectoral surveys, report employment and expenditure data together, while others cover only employment of scientists and engineers either as a major objective or as part of a broader employment survey. A leading example of this type of survey is the biennial survey of employment of scientists and engineers in the Federal Government.[23]

The various surveys differ with respect to definitions of scientists and engineers, and in the level of occupational, industrial and functional detail. Because of differences in method of collection, certain critical concepts, and survey dates, there are substantial difficulties in linking these sources together in a comprehensive picture of employment of scientists and engineers.

Since in most instances the scope and method of data collection are explained in the original reports on the results of the various surveys, elaborate description and explanation of their method are unnecessary. Table 1 summarizes those substantive features of most interest to this study, including whether or not Federal support of employment is explicit, the presence or absence of occupational detail or, alternatively, the field of science, whether or not the character of work is indicated, and whether or not supporting detail on expenditure and costs is included. In all cases the most recent survey available was the basis for categorization.

The various sources of data shown in the table, both those that provide information on employment and those which provide expenditure or cost data, hardly constitute an entity. Most of them have been designed to meet various special needs without regard for uniformity in the scope and nature of the data. Moreover, within any given survey, cross tabulation of one dimension on another is not always possible, for example, in the BLS Survey of Scientific and Technical Personnel, data on character of work are collected only for all scientists and engineers rather than for each of the occupational specialties. Different methods of data collection, even in the coverage of virtually similar populations, also add to the incompatibility of the systems. Nevertheless, BLS has put together a time series for the period, 1950–66, of science and engineering employment covering engineering and the principal natural and physical science occupations,

Table 1. Sources of information on the employment of scientists and engineers in the United States, by selected characteristics

Source and sector	Occupational detail	Federal support	Character of work	Expenditure or cost data
TOTAL ECONOMY				
Census of the United States	X			
National register of scientific and technical personnel	X	X	X	
National engineers register	X	X	X	
Doctorate records file	X	X	X	
PRIVATE INDUSTRY				
Survey of scientific and technical personnel in industry	X	X	X	
Survey of industrial research and development		X	X	X
Economic information system[1]		X		
Survey of employment in atomic energy	X	X	X	
Shipments of defense-oriented industries (MA-175)		X		
HIGHER EDUCATION AND NONPROFIT ORGANIZATIONS				
Survey of scientific activities of institutions of higher education	X		X	X
Survey of scientific activities of non-profit institutions	X		X	X
GOVERNMENT				
Survey of State research and development activities			X	X
Survey of scientific and technical personnel in the Federal Government	X	([2])		
Occupations of Federal white-collar workers	X	([2])		

[1] Conducted by the U.S. Department of Defense and NASA; unpublished.
[2] Civilians only.

[21] Committee on Academic Science and Engineering, Federal Council for Science and Technology. The reports are sponsored by the Office of Science and Technology, and prepared by the *National Science Foundation.*

[22] Of the 14 referred to and listed in the table below, only the U.S. Department of Defense and NASA *Economic Information System* is not available in published form. A number of other scientific and technical manpower surveys are published; for example, the surveys on medical manpower conducted by the National Institutes of Health, but do not receive as wide a distribution and attention as they deserve. In 1964, it was reported that at least 29 Federal agencies collect information on scientific and technical manpower, of which 10 are "major collectors." Gamble, op. ct., p. 103.

[23] The most recent published report in this series is "Scientific and Technical Personnel in the Federal Government, 1966," *Reviews of Data on Science Resources* (NSF 68–16, No. 14, April 1968).

and representing all economic sectors.[24] In evaluating the capability of the science-engineering manpower information system for estimates of federally supported employment, extensive use has been made of this source both as control and, in some instances, as a basis for estimate.

Approaches to measurement of Federal employment support

In the next three chapters, the information sources described above will be tested for their capability in measuring the extent and nature of federally supported employment of scientists and engineers. Two empirical approaches will be used in this test. One has been designated as the budget approach because it utilizes budget data on Federal expenditures as a basis of estimate, in conjunction with published or derived measures of expenditure per scientist or engineer man-year. The other approach has been designated the interindustry transactions approach. This approach uses input-output analysis and occupational patterns by industry as the principal tools of estimation. Both approaches, however, are similar in that they relate employment and expenditure.

[24] *Employment of Scientists and Engineers in the United States, 1950–66* (Washington, D.C., National Science Foundation, 1968).

Chapter III. Extramural Employment of Scientists and Engineers in Federal Programs: Budget Approach

In this and the next chapter efforts to develop measures of extramural employment of scientists and engineers in Federal programs are described. This chapter describes the budget or unit-cost approach. Chapter IV uses an interindustry transaction or input-output table approach. Both approaches are expedients for estimating the Federal effect from sources of data not specifically intended for that purpose. They substitute assumption and analysis for direct measurement for the most part without a means of validating results. A model manpower information system would obtain data on the numbers employed, their occupations and functions, their distribution among program categories, and the associated costs, expenditures and other common measures of program output, directly from extramural suppliers of goods and services to Government programs.

The budget approach simulates a model information system by estimating employment values from assumptions about expenditures per scientist and engineer employed in Federal programs. Expenditure in such programs is assumed to be proportionate, if not equivalent, to program output. Assumed expenditure or, in some instances, reported costs per scientist or engineer are divided into program expenditure to obtain estimates of federally supported employment. All of the estimates discussed in this chapter were produced in this way. The hope was early in the study, however, to locate on-going information systems in various Federal agencies, which would have provided direct estimates of federally supported extramural employment. Recent developments toward such systems are discussed in appendix A.

Estimating extramural employment in Federal programs

Elements of the budget approach. Estimation of federally supported employment of scientists and engineers by the budget approach requires data on (1) total expenditure and (2) expenditure or unit costs per scientist or engineer. Each of these quantities further should be divisible into categories representing the activity or purposes of expenditure, the character of the work performed, the occupational specialties involved, and the various extramural performers or sectors. Expenditure data, of course, must also identify the sources of support and the appropriate Federal budget classification. The general argument and the assumptions underlying the employment estimates are discussed in the following section. Subsequent sections present and discuss the detailed estimates. All of the estimates are in terms of 1966 data.

Estimates of expenditure. The first step in estimating federally supported employment of scientists and engineers was to divide total expenditure into two broad classes representing a Federal and a non-Federal sector. In the Federal sector, however, only expenditures in controllable program categories were included. These expenditures—Federal purchases of goods and services, grants in aid, and subsidies—correspond to Federal Government ouput in the national income and product accounts, and are designated here as Federal program expenditure. Because they mainly involve transfer payments to individuals, such as payments from the retirement and disability trust fund accounts or interest paid on Federal debt instruments, the remaining expenditures were included as part of expenditure in the non-Federal sector. Utilization of scientists and engineers as the result of such expenditures, in other words, was assumed in general to be the same as employment generated directly by other non-Federal expenditures. The aggregate data used are on a calendar year basis [25] to make subsequent estimates of employment congruent with control totals of scientist and engineer employment.

Both the totals of Federal program expenditure and of other expenditure were next divided into two categories representing the character of work. Federal

[25] Calendar year data on Federal expenditures are from Economic Report of the President (February 1968, table B–62), p. 283.

[26] The best source of information on Federal R&D spending is the National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities,* an annual series now in its 17th year of publication.

[27] R&D spending funded by other sources initially was obtained from the National Science Foundation, *National Patterns of R&D Resources* (NSF 67–7, Washington, D.C., 1967), table B–16, p. 23. Later, other sources for particular sectors proved more useful in estimating employment, because of the greater detail available.

spending on research and development[26] subtracted from Federal program expenditure provided estimates of Federal non-R&D spending. Similarly, R&D spending funded by other sources—industry and business, universities and colleges, and other nonprofit institutions—was subtracted from the total of other expenditure, as defined above, to estimate other non-R&D spending.[27]

In summary, as the result of the foregoing operations, estimates of four classes of expenditure were obtained: (1) Federal non-R&D spending; (2) other non-R&D spending; (3) Federal R&D spending; and (4) other R&D spending. The two Federal components include expenditure on scientists and engineers directly employed by the Government as well as those employed in the so-called extramural sectors in Federal programs. As the following section indicates, the difficulty this fact created for estimating federally supported non-R&D employment in the extramural sectors was solved by assuming a uniform utilization ratio and estimating employment as a residual.

Expenditures per man-year and estimates of employment. Estimation of extramural federally supported employment depends on the availability of scientists and engineer man-year expenditures appropriate to the particular dimension of the desired employment estimate. No such man-year expenditures were available for scientists and engineers working in non-R&D functions. Consequently, the unit expenditure used to estimate federally supported non-R&D employment was derived by dividing total non-R&D expenditure—federally supported and supported from other funds—by an estimate of the total non-R&D scientists and engineers.[28] Estimated employment in non-R&D work was then based on a crude assumption that the underlying expenditure ratios would be identical in both Federal programs and in activities supported by other funds.

Estimates of federally supported non-R&D employment were obtained by applying the resulting unit expenditure in non-R&D employment to the estimates of both total and agency Federal non-R&D program expenditure. Division of the latter by the former produced estimates for each of the Federal agencies of federally supported non-R&D employment. Since, however, these estimates included employment in the Federal Government as well as in other sectors, a reduction was necessary to estimate extramural non-R&D employment. Because data on intramural scientist and engineer employment were not available by character of work on an agency basis for 1966, the agency totals of intramural non-R&D employment were also estimated. After deducting the BLS estimate of non-R&D scientist and engineer employment in the Federal Government for all agencies from the estimate of total non-R&D employment, the remainder—extramural non-R&D employment—was distributed among the agencies proportionately to the estimated distribution of total federally supported non-R&D employment.

Estimates of federally supported extramural R&D employment by sector or type of performer were made by more direct, and somewhat more reassuring, methods. For some sectors, expenditures per scientist and engineer in some Federal programs specific to the sector were available or could be derived with relatively small effort. Extramural Federal expenditure on R&D by each agency should have been adjusted at this point to eliminate those fields—psychology and the social and behavioral sciences—for which there are no matching control totals in the NFS-BLS time series on employment of scientists and engineers. Unfortunately, the expenditure data shown in *Federal Funds* is cross classified by agency and extramural performer and by agency and field-of-science only, but no cross classification by performer and field exists. Consequently, estimation of federally supported R&D employment is based on spending in all fields of science and engineering in the various extramural sectors.[29] The sources of data used and the adjustments made are otherwise best discussed with the estimates in the next section.

Estimates of extramural employment in Federal programs

Estimates of federally supported extramural employment of both R&D and other scientists and engineers, by sponsoring agency are shown in table 2. The estimates for both groups were derived by the basic method described in the preceding section, but the methods used to estimate R&D employment differ among the sectors and are further discussed in this section. A distribution by program area, by bridging agency data in some cases, could also have been

[28] Total non-R&D scientists and engineers was estimated as a residual, subtracting R&D scientists and engineers from total scientists and engineers, as given in National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–66,* (NSF 68–30, Washington, D.C., 1968), tables A–1, A–2, pp. 20–23. This source also provided the basic control totals for all sectors as well as the division of employment by character of work.

[29] However, estimates based on other sources were made of *total* federally supported employment by particular field of science. (See chapter 1, table 6.) The inclusion of expenditure in fields of science and engineering other than those considered in this study should not be troublesome. Such expenditure can be regarded as the cost of a complementary input, just as compensation of employees other than scientists and engineers, supplies, etc. are implicitly treated in our unit cost estimates. Adjustment of expenditures by field of science becomes important only when employment in that dimension is under attention.

[30] Such a distribution is attempted in chapter V.

Table 2. Estimated extramural employment of scientists and engineers employed in Federal programs, selected agencies, 1966
[In thousands]

Department or agency	All extramural scientists and engineers	R&D scientists and engineers	Other scientists and engineers
All agencies	261.7	221.5	40.2
Agriculture	5.2	1.5	3.7
Commerce	0.9	0.3	0.6
Defense	128.3	102.5	25.8
Health, Education and Welfare	22.7	18.5	4.2
Interior	1.6	1.0	0.6
AEC	19.3	18.8	0.5
NASA	69.4	69.4	—
NSF	5.2	5.0	0.2
Other	9.1	4.3	4.8

NOTE: Sums of components may not equal total because of rounding error.

attempted at this point.[30] Because most Federal programs are dominated, in financial terms at least, by single agencies, an agency distribution was felt to give results almost as meaningful on a broad level as an approximated program distribution of employment.[31]

Estimates of the employment of R&D scientists and engineers in most Federal programs rest on man-year expenditure estimates specific to particular sectors. The results are shown in tables 3 and 4. For the industrial and business sector, costs per scientist and engineer broken down by source of funds were obtained for DOD and NASA and for all other Federal agencies combined for 200 leading companies in selected industries.[32] Estimates of federally supported R&D employment of scientists and engineers in industry were accordingly built up by applying the appropriate man-year expenditure estimates to agency R&D expenditures on industrial performers. Only the estimates for all industries are shown in tables 3 and 4, however.[33]

The employment estimates for other extramural performers, because of lack of detailed man-year expenditure data, in each case rest on a cruder basis. Considerable adjustment of data were required to derive expenditure per man-year and estimate employment. In each nonindustrial performer sector, reported expenditures from all sources on research and development and full-time equivalent employment of R&D scientists and engineers for the most recent year [34] were first adjusted to conform to the BLS-NSF concepts, by excluding expenditures and employment in the fields of pyschology, the social sciences, and unclassified areas. Further adjustments, in the case of the colleges and universities, independent nonprofit organizations, and their affiliated Federally Funded Research and Development Centers, were made to convert total employment into full-time equivalent units. These adjusted totals of money and manpower were then extrapolated, usually by assumption, to take account of changes between the date of observation and 1966. An adjusted ratio of employment to expenditure was then calculated for each of these sectors.

Expenditures per scientist and engineer obtained after these adjustments were subsequently applied to the respective extramural R&D performer expenditures for each agency, as reported in *Federal Funds*.[35] The estimated employment obtained by applying a common sectoral cost-ratio to each agency's expenditure, however, gave unreasonable results for some performers. Except for independent nonprofit organizations, the alternative procedure adopted for the other nonindustrial R&D performers was, first, to estimate the overall proportion of R&D employment in the performer category attributable to Federal funds.[36] This proportion was applied to the BLS-NSF estimate of total R&D scientists and engineers in the sector in 1966. The estimated total R&D employment for the sector was then distributed among the respective agencies shown in table 3, in accordance with each agency's relative share of R&D expenditure in the performer category.

A common expenditure per man-year for all agencies was used to estimate Federal employment of R&D scientists in independent nonprofit organizations. More than 90 percent of expenditure and manpower in these organizations is devoted to research and development and its administration.[37] About 75 percent of the work of these agencies is federally financed, 80 percent of the funds came from two agencies—the Department of Defense and the Department of Health, Education, and Welfare. It was consequently believed appropriate to apply a uniform average expenditure per scientist and engineer for each agency, after adjustment for increases in both expenditure and employ-

[31] In fiscal year 1969, although as many as 14 different departments and agencies contributed to activities in the fields of commerce and transportation, and 12 were involved in health, labor and welfare programs, less than a third of the agencies were found in three of the functional areas or more. Eight of the agencies were identified with only one broad functional area, and three others included only two such areas in their programs.

[32] National Science Foundation, *Research and Development in Industry,* 1966 (NSF 68–20) 1968, table 46, p. 60.

[33] A two-step process was used to derive estimates of Federal R&D expenditures by industry. Percent distributions of such expenditure for the Department of Defense. NASA and all other agencies were first calculated from NSF, *Research and Development in Industry,* table 45, p. 59. These distributions were then applied to industrial-performer R&D expenditures for each agency, as shown in National Science Foundation, *Federal Funds for Research, Development and Other Scientific Activities* (Vol. XVI, 1967) table C-7, pp. 112–113.

[34] The following National Science Foundation reports were used: *Scientific Activities in Colleges and Universities,* 1964 (NSF 67–17, May 1968) and *R&D Activities in State Government Agencies,* (NSF 67–16, September 1967).

[35] Op. cit.

[36] This procedure was possible because the sources of R&D funds in each performer category were available in the volumes cited in footnote 34.

[37] National Science Foundation, *Scientific Activities of Nonprofit Institutions* (NSF 67–17), p. 5, 1964.

ment since 1964, to Federal R&D funds in 1966.

Because data on expenditure and employment in federally funded Research and Development Centers were available for colleges and universities and independent nonprofit organizations, employment in these wholly supported components needed to be adjusted mainly for fields of science and time. The results have been combined in each case with those for their administratively affiliated category, however. Because *Federal Funds* does not identify support of R&D in State and local governments, an arbitrary allocation of 50 percent of expenditure in the "Other performer" category was made to that sector.

Table 5 is derived from the results obtained with regard to federally attributable employment of R&D scientists and engineers. The implicit expenditure ratios, of course, are the quotient of expenditure divided by employment in each agency performer category. As between performer groups, these implicit ratios appear reasonable; for example, since much of industrial employment of scientists and engineers is in development or applied research,[38] plausibly expenditures per scientist or engineer in that sector may be above average. In colleges and universities, on the other hand, proportionately more effort is devoted to basic research, which typically requires less plant and equipment, supporting personnel, and so forth. In general, the numbers of R&D scientists and engineers employed in an agency performer category depend on the character of the work and the fields of science represented. However, except in a fragmentary way data are not readily available on the latter basis.

Although the relative magnitudes shown in the preceding tables are probably correct for the various agency and performer categories, the estimated numbers, in general, may understate the Federal involvement. The estimates for the NASA are reasonably close to and consistent with the agency's own data.[39] On the other hand, our estimate of industrial scientists and engineers employed in Department of Defense programs, approximately 128,000, falls a bit short of the 130,000 reported for December 1965 by a highly specialized group of defense contractors, which includes only a portion of subcontract employment and no direct employment.[40] Since the definitions of scientists and engineers are the same for the BLS-NSF time series data used as control and the DOD-NASA Economic Information System,[41] if the former provides an accurate estimate of total scientists and engineers either of two possibilities may explain the discrepancy. Our man-year expenditure estimate in the defense space field may be too high, or there has been over reporting of federally supported employment in the EIS surveys. Neither possibility could be investigated in the course of this study, however.

The obviously missing dimension in these cost-based estimates of federally supported extramural employment is occupational specialty. For evaluation of Federal influence in the context of demand and supply of

Table 3. Estimated extramural employment of R&D engineer-scientists on Federal programs by selected agency and performer, 1966

Department or agency	All R&D extramural	Industry[1]	Colleges and universities[1]	Independent nonprofit[1]	State government
All agencies	221,450	161,630	47,400	10,720	1,700
Agriculture	1,540	50	1,475	(2)	(2)
Commerce	285	170	100	(2)	(2)
Defense	102,470	87,400	10,190	4,880	(2)
HEW	18,470	730	13,000	3,540	1,200
Interior	955	250	490	(2)	180
AEC	18,840	6,500	11,475	865	—
NASA	69,460	63,600	5,350	420	90
NSF	5,030	(2)	4,750	270	—
Other	4,400	2,900	570	700	230

[1] Includes federally funded research and development centers.
[2] Less than 50; included in total.

Table 4. Percent distribution, extramural R&D employment of scientists and engineers on Federal programs, by selected agencies and performer, 1966

Department or agency	Performer				
	All extramural	Industry[1]	Colleges[1] and universities	Indepen. nonprofits[1]	State and local government[1]
All agencies	100.0	100.0	100.0	100.0	100.0
Agriculture	0.7	(2)	3.1	(2)	(2)
Commerce	(2)	(2)	(2)	(2)	(2)
Defense	46.3	54.1	21.5	45.5	(2)
Health, Education and Welfare	8.3	0.5	27.4	33.0	70.6
Interior	(2)	1.5	1.0	(2)	10.6
AEC	8.5	4.0	24.2	8.1	—
NASA	31.4	39.3	12.9	3.9	5.3
NSF	2.3	(2)	10.0	2.5	—
Other	2.0	1.8	1.2	6.5	13.5

[1] Includes federally funded research and development centers.
[2] Less than 0.5 percent.

NOTE: Detail may not add to 100 because of rounding.

[38] In 1966, 96 percent of industrial R&D expenditure was allocated to applied research and development. National Science Foundation, Research and Development in Industry, 1966 (NSF 68–20), table 68, p. 82.

[39] If allowance is made for the absence of employment data for the Jet Propulsion Laboratories, NASA reported a total of 66,800 extramural scientists and engineers for June 30, 1967. Our own estimate for a date approximately 18 months earlier is 69,400; NASA's budget at that time was higher than in June 1967.

[40] Calculated from unpublished data supplied by the U.S. Department of Defense, *Plantwide Economic Report* (Economic Information System). The overall proportion of scientists and engineers employed on Federal work in the reporting establishments has been close to 90 percent in recent years.

[41] The reporting instructions for EIS specify that the definition of scientists and engineers is consistent with the National Science Foundation definition, also used in the time-series prepared by BLS. EIS, however, does not exclude psychologists, but this alone would hardly account for the difference.

scientists and engineers, detail on either the occupations or on the related fields of science and engineering involved is essential. Except for the State and local government sector, however, the difficulty is not an absence of sufficient occupational employment detail. What is lacking is a division of expenditure, both total and Federal, along comparable lines. Until expenditure or man-year outlays can be matched to occupational or field of science groups, the budget approach permits no more than estimates of aggregate scientist and engineer employment.

This overview of extramural employment of scientists and engineers should end with a few substantive comments on the pattern of Federal utilization. Keeping in mind the crudity of the techniques of estimation and resulting errors of estimation, it is nevertheless clear that in 1966 Federal spending contributed to a very sizable share of employment in the non-Federal economic sectors. Table 6 shows that an estimated 20 percent of all scientists and engineers in the non-Federal sectors owed their employment to Federal program expenditure. Although private industry as a whole used only about a third of its scientists and engineers on research and development, the estimates in this study indicate that almost 85 percent of private employment supported by Federal programs was devoted to R&D. In particular sectors, especially the colleges and universities and the independent nonprofit organizations, Federal spending may affect more than 70 percent of the scientists and engineers engaged in research and development. Only about 5 percent of non-R&D employment of scientific and engineering manpower, on the other hand, is directly affected by Federal dollars.

Agency (or program) patterns of extramural utilization of scientists and engineers also show significant variation. Although less than 15 percent of such employment is in functions other than R&D, in the older established departments and agencies—the Departments of Agriculture and Commerce, for example—the reverse is the case. (See table 20.) As will be shown in chapter V, such agencies also tend to have a relatively high proportion of their total R&D activity in intramural employment. Agency influence on the R&D performance sectors also varies. The Department of Defense affects more than half of R&D employment on Federal programs in industry, but influences only one-fifth of R&D scientists-engineers employment in colleges and universities, where the Department of Health, Education, and Welfare and the Atomic Energy Commission are more prominent sources of activity. (See table 4.)

An effort to distribute Federal agency employment in R&D by industry produced rather indifferent results,[42] sufficient only to indicate some broad relationships. Industrial employment of R&D scientists and engineers is highly concentrated in the programs of the Defense Department, which result in half or more of federally supported R&D employment in all but one industry covered in the Census-NSF survey.[43] Other agencies have correspondingly smaller effect on federally supported R&D employment. Federal effect on total R&D employment, on the other hand, is much more varied among the industries, partly because of the dependence of the industry on Federal expenditure.

Table 5. Implicit performer cost-ratios, extramural R&D scientists and engineers in Federal programs, selected agencies, 1966

Department or agency	Performer: All extramural performers	Industry[1]	Colleges[1] and Universities	Independent nonprofit[1]	State and local government[3]
All agencies	$53,770	$57,175	$41,500	$53,395	$22,700
Agriculture	45,975	52,000	41,800	(²)	(²)
Commerce	46,300	50,000	38,000	(²)	(²)
DOD	50,050	50,650	41,365	52,830	(²)
HEW	45,100	50,000	41,350	52,850	20,800
Interior	51,600	58,400	40,200	(²)	46,670
AEC	63,300	102,630	41,290	52,830	—
NASA	60,150	61,760	41,270	52,860	34,450
NSF	42,550	(²)	41,100	53,300	—
Other	51,900	54,170	57,720	55,700	9,130

¹ Includes federally funded research and development centers.
² Estimated number of scientists and engineers too small to compute cost ratio.
³ Federal R&D funds for State governments in FY 1966 estimated at 50 percent of the "other" performer category.

Table 6. Total and federally supported extramural employment of scientists and engineers, selected performers, 1966

Character of work and performer	Total extramural	Federally supported	Percent Federal
All activities (in thousands)	1279.2	261.7	20
Research and development	454.5	221.5	49
Industry[1]	370.9	161.6	44
Colleges and universities[1]	65.6	47.4	72
Independent nonprofit organizations[1]	[2]13.6	10.7	79
State and local governments	4.4	1.8	41
Non-R&D	824.7	40.2	5

¹ Includes federally funded research and development centers.
² Estimated from **Scientific Activities of Nonprofit institutions** (NSF 67-17, March 1969).
SOURCES: See text and appendix C.

Evaluation of the budget approach

As demonstrated in this chapter, the budget or man-year expenditure approach does permit estimation of federally supported employment of scientists and engineers. Sufficient information exists to construct

[42] The principal factor inhibiting this exercise is the conceptual difference in reporting employment by industry. Bureau of Census industry groups, in their reports on R&D manpower and expenditure, are based on the *company* as the reporting unit, while the Bureau of Labor Statistics surveys of science and engineering manpower are on an *establishment* basis.

[43] Chemicals, machinery, electrical equipment, motor vehicles, aircraft missiles, instruments, and all other. See *Research and Development in Industry* (NSF 68-20, 1966), table 46, p. 60.

plausible, if not wholly accurate, estimates of such employment. The various dimensions for which estimation is possible, moreover, reveal a substantial amount of information about the structure of the Federal employment effect in all major extramural sectors.[44] In only two, but very important, dimensions—occupation and/or field of science and function—are the sources incomplete or seriously deficient in the ingredients needed to estimate employment.

The principal weakness in the budget approach was found to be on the side of financial and expenditure data. Rather strong assumptions had to be made in allocating aggregate expenditures among Federal programs and agencies, particularly in areas other than research and development. Only two extramural sectors provided any detailed estimates of expenditure per scientist and engineer and thereby necessitated crude assumptions to derive employment estimates for other sectors. Employment data, on the other hand, appear to be adequate for most sectors. Indeed, much more detailed estimates encompassing at least R&D employment by occupation or field of science would have been possible if such data could have been bridged to financial and cost data, appropriately differentiated by funding sources. Efforts to integrate employment and financial data in the fields of science and engineering should therefore be given careful consideration.

No approach to a problem of estimation such as is attempted in this study can exceed the limitations of the sources of data. Apart from the question of modification and improvement in the data sources, however, the merits and limitations of the budget approach as such should be recognized. Its principal merits are, first, that currently it provides the only comprehensive means of estimating Federal employment influence in science and engineering, and, second, that the kinds of data required are already being collected, although not in all sectors. The principal limitation is that the approach is relatively inflexible as a tool of manpower planning in Federal programs. It can provide information on the manpower implications of current changes in support levels within a given program structure. It could also be used to project changes in program requirements, but only if there is a suitable means of projecting both expenditure and man-year outlays.[45] On the other hand, to visualize the utility of the approach for estimating the requirements for scientists and engineers in so-called "new initiative" programs is difficult. The levels of detail on total and man-year expenditures required for such programs, in particular, may make it worthwhile to consider a more direct attack.[46]

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[44] Previous efforts to utilize man-year expenditures as estimators of employment have covered fewer sectors and provide no functional and agency detail. For an example of such an earlier effort, see Melville S. Green, *Studies in Scientific and Engineering Manpower* (U.S. Department of Commerce, Office of Assistant Secretary for Science and Technology, Staff Report 63-1, October 1963).

[45] A pioneering effort to project Federal program expenditure is the work of Gerhard Colm and Peter Wagner, *Federal Budget Projections* (Washington, D.C., Brookings Institution, 1966). The conceptual and measurement problems involved in developing an index of R&D costs are discussed in Helen S. Milton, *Cost of Research Index* (Research Analysis Corp., McLean, Va., March 1966); also see Kathryn S. Arnow, "Indicators of Price and Cost Change in R&D Inputs," and Allan D. Searle, "Measuring Price Change in R&D Purchases," in *Proceedings* (American Statistical Association, Business Economics Section, 1966).

[46] This is not to say that a very rough first cut could not be taken by assuming certain levels of expenditure and unit costs of scientist and engineer employment. See the illustration provided in chapter VI, pp. 29–39.

Chapter IV. Extramural Employment of Scientists and Engineers in Federal Programs: Interindustry Transactions Approach

The results described in the previous chapter provide only a broad picture of the effects of Federal spending on the deployment of scientific and engineering manpower. They confirm more casually constructed or indirect evidence of the concentration of the Government's demand for scientists and engineers in research and development and among certain extramural R&D performers. On the other hand, they provide only a limited view of the industrial structure of program manpower requirements, even in the R&D area, and virtually no occupational detail. Both of these latter dimensions are essential to purposes such as planning for major changes in program support levels or for the introduction and development of substantial new programs.

The relatively new tool of input-output analysis offers a method of overcoming some of the limitations of the budget approach. Input-output analysis consists of manipulating a tabular model of the economy, which displays the transactions among all producing industries and between them and the final demand sectors, including government. The technique has been used for studies of a variety of economic relationships, including studies of employment and manpower requirements.[47] This chapter briefly describes the essential features of the interindustry transactions approach, provides an estimate and some analysis of extramural employment in scientific, engineering and allied occupations resulting from Federal purchases in 1965, and evaluates the approach as a manpower planning tool.

Elements of the interindustry transaction approach

Estimates of the employment of scientists and engineers attributable to Federal expenditure may be derived from so-called interindustry employment tables. These tables show the total employment generated by the delivery of a billion dollars of an industry's output to final demand or to other industries. Total employment is the sum of employment in the industry providing the goods or services and the employment in all supporting industries. The total of a particular industry's employment, therefore, is the sum of employment generated by its gross output, that is, the industry's delivery to final demand and to all other industries resulting from a billion dollars of sales. Application of appropriate occupational patterns or coefficients to this employment total provides estimates of occupational employment in the industry per billion dollars. If the total purchases of the Federal Government, or any of its component programs, and their industrial distribution are known, then the corresponding occupational employment in each industry and in all industries may be estimated.

Acceptance of the results achieved through application of the interindustry transactions approach depends on the acceptability of certain assumptions and limitations about the process and the data. In this section, these assumptions and limitations are set forth. Succeeding sections (1) present the resulting occupational distributions and derived total requirements for scientific and engineering manpower in certain Federal programs, and (2) evaluate the usefulness of the approach in terms of the objectives of a scientific and technical manpower information system.

The interindustry employment tables. Extramural employment of scientific and technical manpower on

[47] A number of employment studies based on input-output analysis have appeared in the *Monthly Labor Review.* See Jack Alterman, "Inter-industry Employment Requirements," (July 1965), pp. 841–850; Richard P. Oliver, "The Employment Effect of Defense Expenditures," (September 1967), pp. 9–16; Max A. Rutzick, "Worker Skills in Current Defense Employment," (September 1967), pp. 17–21. Projections of employment either in terms of the numbers expected as the result of economic growth or in terms of hypothetical social and economic goals, analogous to federally supported programs, are other uses of input-output analysis. See *Projections 1970: Interindustry Relationships, Potential Demand, Employment* (BLS Bulletin 1536, 1966); and Leonard A. Lecht, *Manpower Requirement for National Objectives in the 1970's* (Center for Priority Analysis, National Planning Association, Washington, D.C., February 1968).

[48] Input-output tables are essentially a matrix or grid relating all transactions in the country, including industry sales to other industries and sales, to a final demand sector such as business, households, and so on. Each transaction between industries, which make up the processing sector of the table, is counted twice to reflect the fact that it represents an input as well as an output of an industry. A good introduction to the subject is William H. Miernyk, *The Elements of Input-Output Analysis* (New York, Random House, 1965). A more extensive and more mathematical treatment may be found in Hollis B. Chenery and Paul G. Clark, *Interindustry Economics* (New York, Wiley, 1959)

Federal work may be estimated from interindustry employment tables for the Federal sector of final demand. Such tables are generated from the basic input-output table [48] and show for each billion dollars of Federal purchases the equivalent employment in the supplier industries and their supporting industries.[49] The product of the industry employment coefficients and expenditure on the output of an industry equals the estimated total employment in the industry associated with the expenditure.

The employment estimates used reflect the industrial distribution of total private employment in 1965 and were prepared by the Interagency Growth Project. The input-output tables used to generate these estimates of employment are based on the 1958 table; the technical or product coefficients were adjusted to 1965 and reflect subsequent changes in the technologies of production, changes in the product mix, and changes in factor prices. Such adjustments are necessarily rough, because they have been based on fragmentary information on industrial and technological developments rather than intensive industry studies required for greater precision of estimate.[50]

The Federal Bill-of-Goods. Given industry employment coefficients, the first step in the estimating process is to obtain industrial distributions of Federal purchases of goods and services. Such distributions conventionally referred to as the Federal "bill-of-goods," consist of payments for Federal purchases of goods and services in the private industrial sector. Except for purchases from private educational and nonprofit organizations, this sector corresponds to the industrial and business sector of the private economy. Expenditures on personal services hired directly from the household sector and expenditures in the government sector itself, including government enterprises, are not included in the Federal bill-of-goods.

In addition to purchases of goods and services, Federal aid to State and local governments constitutes a significant and growing proportion of government outlays. In 1965, Federal outlays to such governments were nearly 10 percent of total Federal outlays and about 19 percent of Federal outlays on domestic programs.[51] As presently constituted, Federal grants, loans, and transfer payments to State and local governments are not included in the Federal bill-of-goods, however.[52] On the other hand, there is a bill-of-goods for State and local governments,[53] which includes the expenditure of Federal funds in the industrial aggregates. To estimate the corresponding federally supported employment, a crude bill-of-goods representing the expenditure of Federal funds was constructed from unpublished data adjusted to a calendar 1965 basis. Transfer payments to individuals, under federally supported public assistance and some manpower and poverty programs, and shared revenues were excluded. The amount constituting the bill-of-goods—about $6.8 billion—represents about 9 percent of 1965 State and local government spending,[54] more than two-thirds of which was allocated to the construction of highways and other facilities.

In principle, the total purchases of the Federal Government can be subdivided into any convenient set of industrial distributions representing various functions or programs. In practice, however, such distributions are not easily accessible, but must be painstakingly constructed from various sources of information, including special studies.[55] Consequently, the only ready-at-hand bills-of-goods available divide Federal purchases between defense and nondefense purchases.

Defense purchases, of course, have dominated Federal purchases of goods and services during the past decade; in fiscal year 1965, the year of estimate of scientists and engineers on Federal work, the defense effort absorbed 75 percent of such purchases.[56] The defense bill-of-goods used here includes only those purchases made by the Department of Defense. Some additional defense purchases made by agencies such as NASA and AEC are included in the category "Other government," because the total purchases of those agencies could not be segregated functionally.

Estimating "Federal" Employment. Estimation of the employment attributable to Federal purchases of goods and services in the private sector, thanks to the

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[49] *I.e.,* the industries supplying raw materials, power, services, etc., for *current* production. Input-output tables usually do not include purchases of capital goods as an *input* coefficient. See *Projections 1970,* etc., p. 20; however, much research has been undertaken to solve the problem of empirical estimation of capital coefficients. See Chenery and Clark, op. cit., pp. 149–153.

[50] For further discussions of the nature of such adjustments, see Chenery and Clark, pp. 85–100. A completely revised table of interindustry relations for 1963 was published after this study had been completed.

[51] *Budget of the United States, Special Analysis, Fiscal Year 1970,* table 0–3, p. 209. Probably only about one-third of State-local aid consisted of transfer payments under public assistance and medicaid programs.

[52] The exclusion of these Federal payments is necessary to maintain consistency between the input-output tables and the national income and product accounts.

[53] *Projections 1970,* table IV-4, pp. 63–64.

[54] Data on State and local government expenditures are from Joint Economic Committee, Subcommittee on Economic Progress, *State and Local Public Facility Needs and Financing,* December 1966, p. 37.

[55] Conversations with officers of the General Accounting Office, which warrants the payment of the Government's bills, revealed that there is no coding system which identifies expenditures with programs *and* the supplier industries as classified by the Standard Industrial Classification scheme. It had been hoped that this would be a primary source relating purchases to program activity.

[56] *Budget of the United States, Special Analysis, Fiscal Year 1970,* table A-6, p. 18.

computer, is a comparatively simple mechanical process. Each bill-of-goods is run against an employment inverse, that is, a matrix of employment coefficients arranged by industry, to produce estimates of total employment by industry. These estimates become the base for further estimation of occupational employment in each of the sectors considered; in this case: Final demand, total Federal expenditure, Department of Defense expenditure, and other Government expenditures. Estimates of federally supported employment of scientists and engineers in the State and local government sector, however, could be broken down by Federal department or agency.

Once such employment estimates have been made, it is then comparatively easy to calculate the percentages or ratios of federally supported employment to total employment in each industry and occupation. The percent distribution of the Federal share between defense and nondefense employment in each industry as well as the industrial distribution in each program sector, as noted above, are then calculable as are similar distributions of occupational employment.

Each employment estimate is composed of two parts—direct and indirect employment. For any given industry direct [57] employment is the employment created by direct delivery to final demand or a sector of final use such as the Government. The indirect component of total employment represents employment in the industry created by Government purchases in all other industries. Sales of steel billets to the Government-owned ordnance plants, for example, create direct employment, but Government purchases of shovels create indirect employment in the steel industry. A breakdown of the two types of employment could be useful for manpower planning in Federal programs, although no attempt was made for this study.

Application of Occupational Patterns. The final step short of analysis is to apply occupational patterns or coefficients to the estimates of total industry employment. Federally supported and total industry employment used for this purpose are shown in appendix B. The occupational patterns used included 21 distinctive occupations: Eight scientific occupations, including mathematicians; 10 engineering occupations, and 3 technician groups. The occupational patterns used, and the method of their construction, were adapted from the BLS occupation-industry matrix to correspond to the industry groups of the input-output tables.[58]

The resulting estimates of occupational employment attributable to Federal purchases of goods and services deviate from "true" estimates, since the correspondence of the two schemes of industrial classification is only approximately identical. The selection and classification of the 116 industries in the industry-occupation matrix were governed by interest in particular occupations (mainly those requiring extensive education and training) and by the availability of related historical data sufficient to permit projections of employment. Consequently, the occupational patterns for some industries, for example, construction, are based on broad industrial categories, while others relate to finer industrial groups. The interindustry tables consolidate detailed SIC industries into 86 groups, 77 of which were employed in this study. This scheme of grouping is governed largely by the composition of final demand and its distribution among producing industries. Because of these differences in purpose, the conversion of the industry-occupation matrix to the interindustry base cannot be complete with respect to the relevant occupational patterns, although both schemes exhaust total employment.[59] Until occupational patterns for a greater number of detailed industries are developed on a common base, estimates of occupational employment must be regarded as only a first approximation.

An additional source of error in estimating occupational employment may result from the selective character of Federal purchases among firms in supplier industries. Because of lack of information about the intraindustry distribution of such purchases and corresponding differences in occupational patterns,[60] the assumption has been made that the patterns for the industry as a whole are identical with those of Federal suppliers. In fact, of course, Federal Government procurement is not randomly distributed within industries. In defense procurement especially, a particular company or establishment commonly is designated as "sole source."[61] Such suppliers may have occupational patterns that are unique because of their unique product-mix and the applicable technology involved.

Extramural employment of scientists and technicians

The resulting estimates of extramural employment of scientists and engineers supported by Federal funds are necessarily incomplete without estimates from other sources. As explained earlier, the Federal bill-of-goods covers only a portion of employment outside of the

[57] Sometimes referred to as primary employment.

[58] *Occupational Employment Patterns for 1960 and 1975* (BLS Bulletin 1599, December 1968).

[59] A conversion table developed by the BLS Division of Occupational Employment Statistics was used in this study. The SIC groupings used in the industry-occupation matrix are shown in BLS Bulletin 1599, appendix B, pp. 83–85. The interindustry classification scheme is in *Projections 1970,* table IV-1, p. 58.

[60] The patterns in the BLS occupation-industry matrix are, therefore, the patterns of the average firms in the respective industries.

[61] For example, in fiscal year 1965, 25 percent of procurement by the Department of Defense was through a sole source. The remaining purchases were made by more competitive procurement methods. U.S. Department of Defense, *Annual Report* (Washington, D.C., 1967), p. 415.

Federal Government. Consequently, the overall results, shown below in table 7, include adjusted estimates based in part on the man-year expenditure estimates of employment developed in chapter III.

Several crude adjustments had to be made to estimate federally supported employment in the uncovered sectors. Ratio estimates were used to estimate total employment in publicly controlled universities and colleges to reflect the fact that employment in private higher education is included in the estimates based on the Federal bill-of-goods.[62] Federally supported employment in both publicly controlled higher education and in State and local government, public employment was estimated by applying ratios calculated from the scientists and engineers' registers to control totals in the BLS-NSF time series.[63] This method of estimate was necessary because the registers, despite certain shortcomings, are the only primary source of data on total federally supported employment of scientists and engineers in those sectors. The estimate for the nonprofit institutions sector, on the other hand, is the same as developed in chapter III.

Estimates of federally supported extramural employment in the State and local government sector were made on the basis of a crude bill-of-goods supplied by the Bureau of the Budget. The resulting estimates of employment represent those portions of employment generated in private industry by the purchases of State and local governments and which are assumed to be attributable to grants-in-aid from the Federal Government. Highway and educational facilities construction absorbed more than 90 percent of such funds in calendar year 1965. Despite the substantial amounts involved, the effect on the shares of federally supported employment in private industry, as shown in table 7, is fractionally small.

The addition of estimated employment of federally supported engineers in that sector increases the all-sector total of extramural employment by less than 1 percentage point.

Appendix C shows for the detailed occupations the estimated total employment and federally supported employment resulting from State and local government purchases from private industry. The estimates of occupational employment are questionable, however. In view of the substantial role of the Federal Government in State highway construction, for example, the number and percent (6 percent) of employment of civil engineers are remarkably small. Federally supported mining engineers, on the other hand, are estimated at 27 percent of extramural employment in State and local government programs. Although these estimates could be close to the actual relationship, their implausibility strongly points to the general need for more detailed program-based bills-of-goods and possibly finer industry-occupation patterns.

Several observations of substantive interest may be made on the basis of table 7. First, the overall Federal share of extramural scientist-engineer employment is significantly large. Some comparisons may help to evaluate this share. In 1965, the Government's budget, exclusive of transfer payments and net interest, represented about 12 percent of Gross National Product. Estimates of the direct and indirect effect of Federal spending on total employment in 1965 indicate that the Government's share, again only in private industry economy is about 5 percent. In the broad category, professional, technical, and kindred workers, the Federal portion still only approaches 6 percent of the estimated total. Further, scientists and engineers in all sectors of employment, public and private, were only about 1.5 percent of total employment in 1960, and are projected to increase to a little over 2 percent by 1975.[64] Thus, in 1965 the federally supported share of scientist and engineer employment was 11–14 times greater, relatively, than the total proportion of such employment in the economy.

The Federal effect in particular sectors is even larger than its total effect on the employment of scientists and engineers. The estimates shown in table 7 indicate very large shares of federally-supported scientist-engineer employment in the publicly controlled universities and colleges, and in the privately controlled nonprofit organizations. In these sectors the shares of federally supported employment are 2 to 4 times larger than the sectoral proportions of total science and engineering employment. On the other hand, State and local governments experienced the least effect; even with the addition of federally supported employment in private industry the Federal share is only 13 percent.

Evaluation of the significance of Federal support, however, must look not only at aggregates, but also at its influence on the utilization of particular occupational groups. The degree of utilization and, by impli-

Table 7. Estimated employment of scientists and engineers supported by Federal funds, by type of employer, 1965

Type of employer	Total	Federally supported	Percent Federal
All employers	1,290,300	249,907	19
Private industry[1]	1,088,400	169,827	16
Scientists[2]	224,743	21,965	10
Engineers	863,657	147,862	17
State and local government	83,200	12,480	15
Publicly controlled universities and colleges	104,700	59,300	57
Nonprofit organizations	14,000	8,300	9

[1] Includes medical, educational services, and nonprofit organizations other than State and local government units.
[2] Includes mathematicians; excludes social scientists.

[62] The ratios used were taken from National Science Foundation, *Scientific Activities at Universities and Colleges, 1964* (NSF 68–22, Washington, D.C., 1968), table II, p. 16.

[63] *Employment of Scientists and Engineers in the United States, 1950–1966* (NSF 68–30) table A–1.

[64] *Occupational Employment Patterns* (BLS Bulletin 1599) appendix C., p. 36.

Table 8. Federally supported employment in selected scientific and technical occupations as a percent of total occupational employment, private industry, 1965
[Employment in thousands]

Occupation	Total private industry	Total Federal Government	Department of Defense	Other Federal Government
		In percent		
All occupations	62,326.0	5.2	3.3	1.8
Professional, technical and kindred workers	6,026.8	7.7	5.1	2.6
Scientists and engineers	1,088.4	15.6	11.0	4.6
Engineers, technical	863.6	17.1	12.4	4.8
Engineers, aeronautical	48.3	62.3	51.1	11.2
Engineers, chemical	45.3	10.6	6.4	4.2
Engineers, civil	127.6	7.8	4.1	3.4
Engineers, electrical	186.0	20.0	14.7	5.3
Engineers, mechanical	166.4	16.6	11.8	4.8
Engineers, metallurgical	25.1	15.2	10.3	5.0
Natural scientists	224.7	9.8	5.9	3.8
Chemists	92.9	8.7	4.9	3.8
Agricultural scientists	22.0	6.5	1.8	4.7
Biological scientists	23.4	5.5	2.5	2.9
Mathematicians	25.7	18.0	13.1	4.8
Physicists	22.4	16.6	11.7	4.9
Technicians, except medical and dental	746.0	11.8	8.1	3.7
Draftsmen	246.4	12.2	8.6	3.7

cation, the goods and services to which their services contribute necessarily underlie any judgment about the size of Federal utilization of scientific and technical manpower. Table 8, which shows the estimated shares of federally supported employment in particular scientific and technical occupations as a percent of total occupational employment provides some insights. The table shows considerable occupational variation in the federally supported shares of occupational employment, ranging from under 6 percent (biological scientists) to over 60 percent (aeronautical engineers) of employment. Federally supported employment was generally higher among engineers than among scientists.

Table 8 also shows how the estimated Federal shares of extramural employment were distributed between employment in programs of the Department of Defense and all other Federal programs. Not too surprising is the dominance of the Defense Department in almost every occupation. In only a few occupations, notably civil engineering and agricultural scientists, a major share of the Federal Government's impact is generated by other programs.

For planning purposes, differences in occupational patterns among types of programs may be more relevant than the levels of expenditure involved. Unfortunately, the data available allow an analysis only of broad differences between Federal programs and other patterns of utilization of engineers and scientists. Table 9 indicates that the two Federal occupational patterns are generally similar to each other and to the private economy.

Differences in occupational patterns between the Federal Government as a whole and the total economy clearly appear to be influenced mainly by defense spending. The higher utilization ratios in certain engineering specialties—aeronautical and electrical engineers—is largely because of the relatively large numbers employed in defense programs. In other Federal programs, the engineering pattern more nearly approximates the pattern of the total economy. Federal utilization of scientists and mathematicians is also similar to the total pattern, both in defense and nondefense programs. Such differences in influence among the occupations in part are attributable to the heavy Federal support of applied research and development, on the one hand, and the relatively smaller allocation of Federal R&D funds to basic scientific research.[65]

The differences in occupational patterns between the various sources of expenditure are probably the joint result of two factors. One is the occupational patterns of employment in the various industries, which may differ substantially. The other factor is the industrial distribution of procurement in particular Federal programs. Since, in the inter-industry transactions approach, the individual industry occupation patterns are necessarily assumed to be unchanged from program to program, the industrial mix of the program becomes the principal determinant of the overall occupational pattern of any given program.

The force of the industrial influence is illustrated in tables 10, 11, and 12. Table 10 shows the estimated distribution of total employment at large and in the defense and nondefense areas of Federal program activity. In 1965, the Federal Government procured

Table 9. Percent distribution of scientists and engineers in private industry, selected occupations, by source of support, 1965

Occupation	All sources of support	Total Federal Government	Department of Defense	Other Federal Government
Scientists and engineers (number)	1,088,400	169,827	120,134	49,704
Total (in percent)	100.0	100.0	100.0	100.0
Engineers, technical	79.4	87.1	88.9	82.6
Engineers, aeronautical	4.4	17.7	20.5	10.8
Engineers, chemical	4.2	2.8	2.4	3.8
Engineers, civil	11.7	5.7	4.4	8.7
Engineers, electrical	17.1	21.9	22.8	19.7
Engineers, industrial	8.8	10.0	10.4	9.3
Engineers, mechanical	15.3	16.3	16.4	16.0
Engineers, metallurgical	2.3	2.2	2.1	2.5
Engineers, mining	1.8	0.6	0.5	0.7
Engineers, sales	5.3	4.0	4.0	4.0
Other engineers, technical	8.0	5.8	5.4	6.8
Natural scientists	20.6	12.9	11.1	17.4
Chemists	8.5	4.8	3.8	7.1
Agricultural scientists	2.0	0.8	0.3	2.1
Biological scientists	2.1	0.7	0.5	1.4
Geologists and geophysicists	1.8	0.8	0.7	0.8
Mathematicians	2.4	2.7	2.8	2.5
Physicists	2.1	2.2	2.2	2.2
Other natural scientists	1.6	0.9	0.7	1.3

NOTE: Figures may not add to total because of rounding.

[65] In fiscal year 1965, of the total of $15,731 millions of Federal obligations for research, development, and R&D plant, 31 percent was allocated to research and 11 percent to basic research. The Department of Defense was responsible for more than half of total Federal development spending. These percentages were calculated from *Federal Funds,* Vol. XVI, tables C-78, C-81 to C-84, pp. 212–214.

much more of its goods and services from the manufacturing industries than from other industrial sectors. Federal programs outside of the defense area, however, were relatively large purchasers of goods and services from the nonmanufacturing industries, notably in construction and the service industries. The industrial pattern for engineers and scientists, shown in tables 11 and 12, are generally similar to the pattern of Federal effect on total employment. On the other hand, there are substantial differences between the two occupational groups. Engineers in federally supported programs are more heavily concentrated than scientists in the manufacturing industries, and scientists have a much more substantial representation in the services and other nonmanufacturing industries. Presumably, further breakdown of Federal programs would show even more varied industrial and occupational patterns.

Table 10. Industrial distribution of estimated total employment, by expenditure source, 1965

Industry[1]	All expenditure	Department of Defense	Other Federal Government
All industries (number)	62,326,607	1,918,300	1,154,773
Total (in percent)	100.0	100.0	100.0
Agriculture, forestry and fisheries	7.5	1.3	4.8
Mining	2.9	1.5	1.8
Construction	5.6	4.6	15.1
Manufacturing	29.4	77.6	51.3
Transportation	4.3	(²)	7.1
Communications and public utilities	2.4	3.9	5.9
Trade	24.4	3.7	4.5
Finance, insurance and real estate	5.4	0.3	1.8
Services and miscellaneous	17.7	7.0	10.1

[1] For SIC-related industries, see BLS Bulletin 1536, table IV-1, p. 58.
[2] Less than 0.05 percent.

NOTE: Figures may not add to total because of rounding.

SOURCE: Appendix table A.

Evaluation of the interindustry transactions approach

As a method of measuring Federal influence on the employment of scientific and technical manpower and as a tool for manpower planning, the interindustry transactions approach on balance is a promising technique. Conceptually, it consists of a set of simultaneous equations representing a set of interrelated production functions, in which output is treated uniformly between industries and among various bills-of-goods. For program planning in which the focus is on manpower requirements, this feature is an analytical advantage. Although some limitations exist, the major difficulties are found not in the technique itself, but in the underlying information system. Therefore, separating these two aspects is essential in evaluating the approach.

Given the availability of the basic input-output table, the interindustry transactions approach potentially has several very strong technical advantages: Comprehensiveness, internal consistency, analytic compatibility, and adaptability. The first and second advantages are inherent in the input-output tables. Such tables, by definition, must account for *all* transactions in the economy.[66] Hence, the resulting employment relationships are comprehensive, irrespective of the varying quality of the data in the cells of the employment matrix. Both direct and indirect employment are also estimated. By the same token the employment coefficients and estimates generated by an input-output table are internally consistent, that is, the same method of estimating employment is not only applied to each of the industries but also resulting employment in the rows of the table must equal the column totals. This will be the case whether total employment or employment in a particular occupation is under consideration. An especially strong feature of the approach is its compatibility with various analytic sources of data, partly by design as in the case of the national income accounts with which the input-output tables share a common source of data as well as conceptual similarity, and partly by linkages to employment and other data via the Standard Industrial Classification system. Because of this feature, the interindustry approach readily lends itself to the analysis of dynamic changes in the growth and structure of the economy, including projections of employment requirements. Finally, in principle the interindustry transactions approach is highly adaptable, since both the sources of demand and the resources required to satisfy varying sources of demand can be disaggregated to a relatively fine level of detail. In employment analysis, the resulting detail of structure can be especially useful.

As presently designed, the interindustry transactions approach seems to have at least two disadvantages, viewed from the perspective of the occupational employment effect of Federal programs. One of these is that the occupational patterns related to any particular source of employment are purely a function of the industry mix. In this respect, the same occupational pattern applies whether the delivery of the industry's output is to total final demand or to any segment of that total such as the Federal defense sector. Yet, occupational patterns can vary markedly within industries as the result of differences in product mix, as in electronics, for example.[67] This difficulty might be

[66] For the purpose of measuring Federal effect, the national economy usually is the relevant base for the input-output model. However, it is also possible to construct input-output models representing transactions within a region and between regions in a national economy. For a brief discussion of regional input-output analysis, see William Miernyk, op. cit., chapter 4, pp. 58–77.

[67] The occupational distributions of the military-space and the consumer products sectors differ greatly in electronics manufacturing. See *Employment Outlook and Changing Occupational Structure in Electronics Manufacturing* (BLS Bulletin 1363, 1963), p. 37. See also the discussion in Joseph F. Fulton, "Employment Impact of Changing Defense Programs," *Monthly Labor Review* (May 1964), pp. 511–513.

reduced, but not altogether eliminated, by a larger, more detailed input-output table and correspondingly more detailed employment coefficients and industry employment patterns. However, this difficulty is not unique to input-output analysis, but is a limitation on most other practical approaches to estimating occupational requirements.

The other disadvantage, which, however, may be particularly apt to Federal program activity, is that the approach is relatively insensitive to changes in the job content of occupations, especially the character of work. Occupational requirements for a planned Federal program derived by the interindustry approach in the manner described in this chapter will not be meaningful if the related job content is radically different. The NASA experience is opposite to this point, namely the need to develop a unique scheme of occupational classification reflecting the job content of its own work force. Similarly, the approach has no practical way of descriminating among the various uses of scientific and technical manpower, especially between R&D and other work performed by scientists and engineers.

For practical purposes, however, the limitations just discussed appear to be tolerable. Other approaches to estimating manpower requirements for new Federal programs and developments would encounter similar problems of undifferentiated occupational patterns and significant differences in job content. Supplementary information and special care in interpreting results should be sufficient in most cases to deal with these problems.

Deficiencies and gaps in the basic sources of data may impose a more serious limitation on the potential use of the interindustry transactions approach in the near future. The results illustrated in this chapter cover only private industry and a segment of State and local government. Other sectors in which there is substantial Federal support, such as higher education and other nonprofit organizations, remain practically uncovered. Estimates of employment in these sectors not only had to be derived by other means, but also lacked corresponding occupational detail. Presumably both aspects for those and similar sectors could be developed and the sectors integrated into a basic input-output table. So far as is known, data sources adequate for this purpose do not yet exist.

A subsidiary issue of possible future importance is the reliability of the occupational coefficients used in estimating occupational employment. How important this issue may be depends on the degree to which occupational detail is wanted. Total industry employment generated by the interindustry technique is derived from coefficients based on establishment payroll reports. The general basis for the occupational matrix, on the other hand, is the decennial census adjusted for broad occupational groups and a few detailed occupations with data from the Monthly Report on the Labor Force, to reflect changes in intercensal periods. The occupational coefficients for all of the scientific occupations and for total engineering employment applied in this study, however, were based on establishment data, which are believed to be more reliable. Only the breakdown of the engineering specialties was based on census sources.[68] Should the need arise for more extended occupational coverage of federally supported employment, increases in the error of estimated occupational employment are likely because of the present patchwork character of the industry-occupation matrix.

Table 11. Industrial distribution of estimated engineering employment, by source of support, 1965

Industry	All sources	Department of Defense	Other Federal Government
All industries (number)	863,657	106,803	41,058
Total (in percent)	100.0	100.0	100.0
Agriculture, forestry and fisheries	0.3	(1)	0.3
Mining	4.4	0.9	1.4
Construction	8.7	1.9	7.4
Manufacturing	64.4	91.2	80.1
Durable goods	55.4	88.8	74.2
Nondurable goods	9.0	2.4	5.9
Transportation	(1)	(1)	(1)
Communications and public utilities	4.3	1.0	2.0
Trade	1.8	(1)	0.2
Finance, insurance and real estate	0.4	(1)	(1)
Services and miscellaneous	14.7	4.8	8.0

[1] Less than 1/10 of 1 percent.

NOTE: Figures may not add to total because of rounding.

Table 12. Industrial distribution of estimated scientist employment, by source of support, 1965

Industry	All sources	Department of Defense	Other Federal Government
All industries (number)	224,743	13,311	8,646
Total (in percent)	100.0	100.0	100.0
Agriculture, forestry and fisheries	7.6	1.5	12.1
Mining	7 7	4.8	3.0
Construction	0.8	(1)	0.7
Manufacturing	53.3	77.2	67.2
Durable goods	20.0	61.3	34.1
Nondurable goods	33.3	15.9	33.1
Transportation	—	—	—
Communications and public utilities	0.7	0.3	0.3
Trade	2.0	0.3	0.2
Finance, insurance and real estate	0.4	(1)	(1)
Services and miscellaneous	27.5	15.4	16.1

[1] Less than 1/10 of 1 percent.

NOTE: Figures may not add to total because of rounding.

[68] For a complete explanation of the construction of the occupational employment patterns, see BLS Bulletin 1599, pp. 4–8. Consideration was given to the BLS *Survey of Scientific and Technical Personnel in Industry* as an alternative source of occupational patterns. The necessary ingredients—total employment in an establishment and occupational detail—are collected in the scientific, professional, and technical personnel programs within the framework of the Standard Industrial Classification. The degree of occupational detail is much less than in the patterns used, however, consisting of four distinctive physical science occupations, two life science occupations, and mathematicians, but no detailed engineering specialties. Considering this limitation, the very large amount of preparation required to construct alternative patterns did not seem worthwhile.

In contrast to the foregoing, the data base and industrial classification scheme of the interindustry tables may conceal useful information. As noted, the Federal bills-of-goods currently available include only purchases of goods and services; other Federal program-related expenditures, especially grants-in-aid to State and local governments, are excluded. It was possible to construct a partial Federal bill-of-goods representing Federal expenditure in this sector, but the results aggregate scientists and engineers employed in publicly controlled universities and colleges with those employed in other State and local governmental functions. Scientists and engineers employed in privately controlled institutions of higher education are also lumped with those serving in other institutions, including nonprofit organizations. Employment in public and quasi-public institutions in 1965 probably constituted over 10 percent of total scientist and engineer employment, and played a proportionately even larger role in Federal programs. It is an anomaly that there is substantial detail on the disbursement and use of Federal funds in these performer sectors, but little or no information on the resulting deployment of manpower. An expanded bill-of-goods including colleges and universities and nonprofit organizations as distinctive sectors and corresponding occupational patterns might be considered as one solution to this problem.

The foregoing considerations tend towards one overall conclusion. The interindustry transactions approach is a useful and adaptable tool for estimating or measuring the manpower implications of Federal programs, but its effectiveness is highly dependent on the quantity and quality of the data employed. This chapter has indicated some of the deficiencies in the data available insofar as they relate to Federal programs. Overcoming these deficiencies would not in itself make use of the interindustry transactions approach superfluous, but reserved for later discussion and judgment is the practical question of how the data deficiencies might be remedied.

Chapter V. Scientists and Engineers in the Federal Government

In terms of accuracy of estimate and occupational detail, information on the employment of scientists and engineers in the Federal Government is unmatched in any other sector. Since at least 1954, the U.S. Civil Service Commission in cooperation with the National Science Foundation has developed a continuing survey of scientific and technical manpower covering all but a few of such employees in Federal departments and independent agencies. The occupational classifications are convertible to those used in other sectors, but provided in greater and more specialized detail. With the introduction of a scheme of functional or character of work classification in 1967, the results of future surveys should be analytically even more useful than those already available.[69]

The distribution of Federal scientists, engineers and allied occupations by program categories is a significant dimension of the total effect of Federal program activity and expenditure. Employment of scientific and technical manpower in the Federal Government has been increasing much more rapidly than total Federal employment. Federal scientists and engineers constitute a substantial fraction of total employment in the scientific and technical occupations as well as in some particular occupations, although in recent years this fraction has not been growing. In some particular occupations intramural employment may represent a very sizable, even a major share of federally supported science and engineering employment.

Several sources of data are combined in this chapter to achieve two objectives. One of these, is to estimate by scientific and engineering specialty the share of in-house Federal employment in total occupational employment. The other objective is to distribute employment in selected science and engineering occupations into categories representing the structure of Federal programs. As background, a brief account of trends in the employment of scientists and engineers in the Federal Government is provided.

Recent trends in Federal scientist and engineer employment

In 1966, 193,000 scientists, engineers and certain health personnel were reported to be employed by the Federal Government.[70] Even on a more restricted definition, mainly excluding health personnel and the social and behavioral sciences, the employment of 131,000 remaining scientists and engineers is impressive. Federal employees were nearly 10 percent of the total employed in scientific and engineering occupations in 1966; Federal employment in all occupations was only about 4 percent of total nonagricultural employment.

Growth of employment of scientists and engineers in the Federal Government during the post-World War II years has been markedly greater than the growth of the Federal civilian work force. Table 13 shows that the total Federal work force was nearly stable throughout the period, increasing by less than 2 percent. At least since 1957, on the other hand, Civil Service scientists and engineers have been increasing by an annual rate of more than 4 percent. The number of physical scientists, mathematicians and engineers in the Federal service in 1965 was nearly twice the number in 1951. Scientists more than doubled their numbers, and engineers increased their numbers by about 75 percent. By 1965, the proportion of scientists and engineers in the Federal civilian work force was more than twice the proportion of scientists and engineers in the country.

Science and engineering employment in all sectors, however, has been growing more rapidly than Federal employment in these occupations. The estimated share

Table 13. Total civilian employment and scientists and engineers, Federal executive branch 1951–65
[In thousands]

Total	Total employment	Scientists and engineers	Percent of total	Scientists[1]	Engineers
1951	2,456.0	70.7	2.9	25.6	45.1
1953	2,532.0	84.9	3.4	33.1	51.8
1955	2,371.0	81.5	3.4	32.7	48.8
1957	2,391.0	90.1	3.8	36.5	53.6
1959	2,355.0	97.7	4.1	39.2	58.5
1961	2,407.0	102.2	4.2	40.4	61.8
1963	2,490.0	120.3	4.8	47.3	73.0
1965	2,496.0	132.0	5.3	52.4	79.7

[1] Excludes social scientists, psychologists, health personnel.

SOURCE: Total Federal employment, **Budget of the United States, Special Analysis I, 1970,** table 1-4, p. 109; engineers and scientists, from NSF, **Employment of Scientists and Engineers in the United States, 1950–66,** (NSF 68–30), tables A1 to A4.

[69] See discussion in section on "Data Gaps in Federal Employment Statistics."

[70] *Scientific and Technical Personnel in the Federal Government, 1966,* National Science Foundation (NSF 68–16, 1968), p. 1.

Table 14. Total and Federal intramural scientists and engineers selected years, 1951–65

[In thousands]

Year	Total scientists and engineers	Federal scientists and engineers	Percent Federal	All scientists	Federal scientists	Percent Federal	All engineers	Federal engineers	Percent Federal
1951	606.1	70.7	11.7	159.0	25.6	16.1	447.0	45.1	10.1
1953	741.9	84.9	11.4	189.6	33.1	17.4	552.2	51.8	9.4
1955	806.3	81.5	10.1	208.5	32.7	15.7	597.8	48.8	8.2
1957	952.7	90.1	9.4	248.9	36.5	14.7	703.8	53.6	7.6
1959	1,051.3	97.7	9.3	287.5	39.2	13.6	763.8	58.5	7.6
1961	1,144.6	102.2	8.9	316.0	40.4	12.8	828.5	61.8	7.5
1963	1,273.5	120.3	9.4	355.1	47.3	13.3	918.3	73.0	7.9
1965	1,361.3	132.1	9.7	395.5	52.4	13.2	965.8	79.7	8.2

SOURCE: **Employment of Scientists and Engineers in the United States, 1950–1966** (NSF 68–30).

of intramural employment fell from 12 to under 10 percent of total science and engineering employment during the 1951 to 1965 period, despite very large increases in the absolute numbers during the period. (See table 14.) The decline appears to have slowed in 1957, however, and the shares of Federal scientists and engineers have since remained more or less stable. A contributing factor may have been the relatively slow rate of growth of intramural Federal spending on research and development, which has been increasing at roughly half the rate of total Federal support of science and technology.[71]

Intramural occupational employment patterns

Employment of scientists and engineers in the Federal Government varies among occupations as a share of total occupational employment. Table 15, which shows the extent of such variation, was constructed from NSF-BLS estimates of occupational employment by sector.[72] To maintain consistency with occupational estimates developed in chapter IV, the estimates are for 1965.

Engineers employed in the Federal Government outnumber scientists in the ratio of 3.2. However, only about 8 percent of all engineers are Federal employees, but approximately 13 percent of scientists in 1965 were in the Federal service. In some particular occupations, the Federal share is more than twice the overall share of all scientific occupations, as in the case of agricultural scientists. Such differences undoubtedly reflect differences in the scientific and technological requirements of different Federal programs. Accordingly, the next section is an effort to distribute occupational employment in the Federal Government by broad program categories.

Government scientists and engineers in Federal programs

Data on employment of scientists and engineers in the Federal Government currently are available only in terms of the agencies in which they work. To convert agency employment of an occupation to a program basis, each occupation was assumed to be distributed among programs in the same proportions as total white-collar employment in Federal agencies. The distribution of white-collar employment among programs, however, also had to be estimated. To make a program distribution of employment it was assumed that if an agency contributes directly to more than one program, its white-collar employment is proportionate to its current expenditure, exclusive of trust and similar funds, in each program.

Table 16 shows how agency white-collar employment was distributed in program categories. The employment data on which the percentages are based is for October 31, 1967, because the U.S. Civil Service Commission did not conduct a survey of Federal white-collar employment in 1965. A finer departmental or agency breakdown, such as is available for total civilian employment in the Budget,[73] undoubtedly would produce somewhat different distributions among the program categories, including fewer employees in the "Other Programs" category. Such a breakdown is not available for white-collar workers or for any of the scientific and engineering occupations, however.

Table 17 summarizes the program distribution of scientists and engineers employed in the Federal Government in October 1966. The occupational data are

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[71] In the period 1955 to 1965, total Federal support of R&D increased 477 percent, but intramural R&D spending increased by only 245 percent, resulting in a reduction of the latter from 37 percent in 1955 to 22 percent of Federal R&D spending in 1965. National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities* (Vol. XVI, NSF 67–19), table C-86, p. 216. A variety of reasons could account for the shift in the composition of federally supported R&D employment. A sensitive manpower information system could detect some of these factors, such as program developments affecting the functional requirements for scientists and engineers, or shifts in the structure of Federal programs.

[72] As reported in National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–66* (NSF 68–30, September 1968).

[73] For example, see *Budget of the United States, Special Analyses, Fiscal Year 1969* (table F-1, p. 71).

from a recent National Science Foundation report,[74] based on information supplied by the U.S. Civil Service Commission. The occupational classes used have been adjusted, principally by grouping detailed occupations, to conform to those used in the historical employment series,[75] and thus are comparable with the definitions of scientists and engineers in other sectors. Before grouping, however, each detailed occupation was distributed in accordance with the white-collar employment distribution shown in table 16 and discussed previously. This method undoubtedly results in some distortion from a true program distribution of Civil Service scientists and engineers. Although no independent means of checking the validity of the resulting distributions is available, apparently the numbers actually employed in the areas of national defense and of commerce and transportation may be larger than indicated, and the agricultural resources and health and welfare areas may be smaller than these estimates.

In terms of relative orders of magnitude, total in-house employment of scientists and engineers generally is similar to the occupational pattern of federally supported employment in other sectors. Employment in national defense programs makes up nearly half of the total for all such occupations. Defense employment, furthermore, is more heavily concentrated among the engineering occupations than among the scientific specialties except for mathematicians and physicists. A detailed breakdown of occupational employment by program is shown in appendix E.

Data gaps in Federal employment statistics

From a methodological viewpoint, the degree of detail on occupational employment in agencies or programs considerably exceeds the level available in other sectors. There are no open-ended categories. Thus the "other occupation" category for scientists and engineers in the Federal service does not have the same meaning as in the other sectors.[76] Again, this is an instance of data "loss" resulting from the incompatibility of definitions and classifications of different Federal statistical systems.

Two data gaps limit the coverage and the analytic utility of data on scientists and engineers employed in the Federal Government. One is the problem of estimating the uniformed scientists and engineers employed in the Armed Forces. The other is the issue of the functional distribution of scientists and engineers in all branches of the Government.

Military personnel working as scientists or engineers may constitute a significantly large group of federally supported scientific and technical manpower. Although accurate and meaningful data on employment and occupation are not available, the number of uniformed personnel currently working as scientists and engineers may approach 25,000. Recent estimates from the national registers show nearly 6,000 scientists employed in the Armed Forces in 1966,[77] and 1,300 engineers in the military and public health services in 1964.[78] However, a special study, covering so-called engineering occupations, indicates that the four services in 1967 had manning requirements for nearly 18,000 advanced degree holders, but an additional 7,000 with bachelor's and first professional degrees—mainly in the Air Force —also may have been working in scientific and technical engineering assignments.[79] On the other hand, nearly 34,000 military personnel held scientific and engineering degrees in 1967. Discussions with Department of Defense manpower specialists indicate that neither the Department as a whole nor the individual services have the information capability for estimating scientist and engineer employment. There is no uniform occupational classification scheme among the services, and no means of converting the categories used to a common scheme, principally because no

Table 15. Total and intramural employment of scientists and engineers, engineers, selected occupations, 1965

[In thousands]

Occupation	All employees	Federal employees	Percent	Federal as percent of total
All scientists and engineers	1,361.3	132.1	100.0	9.7
Engineers, technical	965.8	79.7	60.3	8.3
Scientists	395.5	52.4	39.7	13.2
Chemists	116.0	8.2	6.2	7.1
Agricultural scientists	44.7	15.5	11.7	34.7
Biological scientists	55.6	6.4	4.8	11.5
Geologists, geophysicists	23.6	2.8	2.1	11.9
Mathematicians	48.9	3.8	2.9	7.8
Physicists	39.0	5.6	4.2	14.4
Other scientists	67.7	9.3	7.0	13.7

SOURCE: National Science Foundation, **Employment of Scientists and Engineers in the United States, 1950–1966** (NSF 68–50, September 1968). Tables A-1 to A-11.

[74] "Scientific and Technical Personnel in the Federal Government, 1966," *Reviews of Data on Science Resources* (NSF 68–16, No. 14, April 1968), table A, pp. 14–16.

[75] The detailed occupations included, excepting medical scientists and the groupings follow those in National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–1966,* pp. 49–51.

[76] "Other" categories in most employment surveys usually reflect either specialized occupations too small in number to justify separate classification or, more often, occupations whose unique characteristics present unusual problems of classification. Ambiguity of response may also contribute to classification in this open-ended category. In contrast, the "other" categories used to distribute Federal Government scientists and engineers in this study resulted only from the exclusion of certain detailed occupations which, however, have distinctive classification in the Civil Service scheme.

[77] *American Science Manpower,* 1966, National Science Foundation (NSF 68–7, Washington, D.C., 1967), tableA–8, p. 67.

[78] *Engineering Manpower in Profile,* Engineers Joint Council (New York, 1964), table 5, p. 16.

[79] "Engineers in Uniform," Engineering Manpower Bulletin (Manpower Bulletin No. 9, December 1967).

Table 16. Percent distribution of agency white-collar employment in the Federal Government, by program, selected agencies October, 1967

[In thousands]

Department or agency	All programs	National defense	International affairs	Space	Agriculture	Natural resources	Commerce transportation	Housing development	Health labor and welfare	Veterans affairs	Other programs
All agencies	1,926.1	32.8	1.8	1.5	3.4	3.5	3.9	0.7	5.8	6.0	40.4
State	24.5	—	99.0	—	0.6	—	—	—	—	—	0.4
DOD	629.9	98.0	—	—	—	2.0	—	—	—	—	—
Interior	53.5	—	—	—	—	91.0	—	—	9.0	—	—
Agriculture	85.2	—	13.0	—	78.0	9.0	—	—	—	—	—
Commerce	24.8	—	—	—	—	—	100.0	—	—	—	—
Labor	9.5	—	—	—	—	—	—	—	100.0	—	—
HEW	96.9	—	—	—	—	—	—	—	100.0	—	—
AEC	7.0	100.0	—	—	—	—	—	—	—	—	—
HUD	14.5	—	—	—	—	—	—	100.0	—	—	—
NASA	29.2	—	—	100.0	—	—	—	—	—	—	—
TVA	6.7	—	—	—	—	100.0	—	—	—	—	—
VA	116.2	—	—	—	—	—	—	—	—	100.0	—
Other agencies or departments	828.2	—	—	—	—	—	—	—	—	—	100.0

SOURCE: U.S. Civil Service Commission, **Occupations of Federal White-Collar Workers,** October 31, 1967 (Washington, D.C., 1968), table E.

operational purpose would be served by such a system. Since the primary duty of uniformed personnel is generally defined as a military function, less attention is paid to the technical requirements of particular military jobs with exception of those which may be unique to the services.

The other gap in the data on employment of scientists and engineers in the Federal Government is the lack of a functional breakdown. Until recently, only very crude estimates of the functional breakdown of Federal scientists and engineers have been made. In 1967, the U.S. Civil Service Commission in cooperation with the National Science Foundation instituted a functional classification of scientists and engineers, using a 20-category code to identify various functions.[80] Preliminary results of this new reporting scheme indicate that in May 1967 about 30 percent of scientists and engineers in the Federal Government were engaged in research and development. A final report of the results is expected to be published in the near future.

Table 17. Civilian scientists and engineers in the Federal Government, by program, October, 1966

Program	Scientists and engineers	Natural scientists[1]	Engineers
All programs	131,087	54,255	76,832
National defense	61,492	14,468	47,024
International affairs	3,097	2,338	759
Space research and technology	13,646	4,769	8,877
Agriculture and agricultural resources	15,605	13,202	2,403
Natural resources	16,097	8,352	7,745
Commerce and transportation	9,098	4,208	4,890
Housing and development	554	5	549
Health, labor and welfare	5,803	4,346	1,457
Veterans affairs	1,527	1,021	506
Other programs	4,168	1,546	2,622

[1] Includes mathematicians.

Summary and evaluation

Since by definition and institutional relationship all scientists and engineers employed in the Federal Government are also federally supported, there is no ambiguity in determining the relationship of their employment to Federal spending. The effect, so to speak, is 100 percent. The data source available for this group, moreover, is detailed and amenable to consolidation into categories comparable with the occupational definitions applied to other sectors. At the time of this study, data on the functional character of Federal employment were being developed. The absence of data on the utilization of scientists and engineers in the Armed Forces, on the other hand, is also of some consequence.

The principal deficiency in the intramural sector, however, is the absence of a program classification. A crude rearrangement of agency employment in 1966 has been attempted, to show the relationship of science and engineering employment to the broad goals of the Federal Government for planning purposes. Indeed, it is only in this sector that plausible distributions of scientist and engineer employment both among programs *and* in sufficient occupational detail were possible. If similar and comparable constructions were possible for all other sectors, even at the broad level achieved in the Federal Government sector, it would be an important step toward a manpower information system capable of measuring Federal influence.

[80] A description of the functional classes and the reporting requirements are in U.S. Civil Service Commission, *Federal Personnel Manual System, FPM Letter,* No. 293–9, March 24, 1967.

Chapter VI. Total Federal Effects and Implications for the Scientific and Technical Manpower Information System

The attempt to estimate employment of scientists and engineers supported by Federal funds in each of the various economic sectors has been completed. Three tasks remain: (1) To consolidate the results, bringing together intramural and extramural employment estimates to measure the total effect of Federal spending; (2) to provide illustrations of some applications of the methods of estimate with data presently available; and (3) most important of all, to evaluate the scientific and technical manpower information system and to recommend lines of improvement and further study of the Federal effect. These are the objectives of this chapter.

Total Federal effect on employment

Federal programs vary with respect to both their shares of the total utilization of Government-supported employment and the proportion of scientists and engineers employed in the Federal service. Table 18 shows the estimated employment of scientists and engineers according to the source of support and the program categories of those supported by Federal funds. Both employees of the Federal Government (except military personnel) and those employed in other sectors are included in the estimates of federally supported employment. Although a little less than an estimated 30 percent of all scientists and engineers employed in 1966 were supported by Federal funds, the table readily indicates that more than half of this number were employed in national defense programs. This proportion is probably on the conservative side, since some scientists and engineers classified in other areas, for example, space research, are known to be working in activities directly or indirectly related to defense. Finer program detail and identification of expenditure and, at least, intramural employment would have permitted a more accurate distribution of employment.

Estimates of the proportions of scientists and engineers employed in the Federal Government in each of the program areas are also shown in table 18. Differences in the extent of in-house employment among the programs are quite marked. There is no easy generalization about these differences, which range from 16 percent of program employment in space research and technology to more than 90 percent in commerce and transportation. The nature of the complementary inputs used in the program, for example, experimental space vehicles, the nature of the program output, especially the clientele directly served,[81] the existance of established government-owned facilities, such as laboratories and agricultural experiment stations, and the pace of legislative and environmental changes in the area comprehended by the program, are undoubtedly among the factors contributing to such differences. Direct and intensive study, is needed to establish the particular factors involved and to evaluate their respective influences. For the time being, however, even estimates as crude as these have some analytic value, as will be demonstrated in the next section.[82]

Tables 19 and 20 are distributions of federally supported employment of scientists and engineers by sector as well as source of support. The employment estimates in this instance are for 1965, instead of 1966, because of the need to key the estimates of all other sectors to the largest sector, private industry. Estimates of Federal effect for that sector are based on the interindustry transactions approach, for which data were available only for 1965. Table 20 again shows that the overall Federal effect is nearly 30 percent of the total of employed scientists and engineers. Although precise data are not available, this estimated share probably would not be significantly affected by the addition of scientists and engineers in the armed services. Such additional data, of course, would alter the proportions of in-house employment and the occupational profile of Federal manpower utilization; very likely the engineering occupations, mainly located in the defense programs, would show heavier concentrations of Federally supported employment.

The percent of federally supported extramural employment, as shown in the tables varies between the sectors, the largest extramural sectoral shares occur in the universities and colleges and the independent nonprofit organizations.[83]

[81] For example, agricultural or the industrial and business community. In such programs, a substantial part of the program output is information rather than physical services.

[82] See pp. 30–33.

[83] A number of such nonprofit organizations are almost completely dependent on government contracts and grants. See chapter II, this bulletin, pp. 3–16.

Table 18. Estimated Federal utilization of scientists and engineers, selected programs, 1966
[In thousands]

Source of support and program	All scientists and engineers	Percent	Percent employed in Federal Government
All sources of support	1,412.5	100.0	9.3
Federally supported	392.8	27.8	33.4
National defense	209.1	14.8	29.4
Space research and technology	83.0	5.9	16.4
Agriculture and agricultural resources	20.8	1.5	75.0
Natural resources	17.9	1.3	89.9
Commerce and transportation	10.0	0.7	[1]91.0
Health, labor and welfare[2]	33.7	2.4	17.2
Other Federal programs	18.3	1.3	51.4

[1] Excludes employees of the Post Office.
[2] Includes National Science Foundation.
SOURCES: Tables 3, 5.

Two of every three scientists and engineers involved in Federal programs are located in one or another of the four extramural sectors, but, as earlier analysis of federally supported R&D employment indicates, they are apparently concentrated in a few program areas.

Data gaps affecting the functional and occupational dimensions partially block further analysis of the total Federal effect on the employment of scientists and engineers. The blockage is partial because data deficiencies in these two dimensions vary among the sectors. Occupational or field-of-science estimates of Federal effect are more or less satisfactory for private industry, universities and colleges, and the civilian branches of the Federal Government. Such a breakdown, on the other hand, is not possible for either the independent nonprofit organizations or State and local governments.

In both of these sectors, there are no Federal expenditure data by field of science, even for R&D scientists and engineers.[84] Sectoral breakdowns of employment of scientists and engineers in terms of the character of the work are possible on a crude basis for all sectors, but the estimated employment of R&D scientists and engineers in the Federal Government is at present dependent on an extrapolation of trends in R&D costs per scientist-engineer man-year and Federal spending on research and development.[85] The estimates of federally-supported employment by character-of-work and by field-of-science, and in each case by sector involved, are shown in tables 21 and 22. Regrettably these two dimensions cannot be concurrently analyzed in the framework of Federal spending and programs, since there is ample evidence of field-of-science variation in cost per man-year.[86]

Table 19. Estimated employment of scientists and engineers, by source of support and sector, 1965
[In thousands]

Sector	All sources	Federal support	Other support
All sectors	1,361.3	393.4	967.9
Federal Government[1]	132.1	132.1	—
Other sectors	1,229.2	261.3	967.9
Private industry	960.9	169.8	791.1
Universities and colleges	171.1	68.3	102.8
Independent nonprofit organizations	14.0	10.7	3.3
State and local government	83.2	12.5	70.7

[1] Civilian only.
SOURCE: Scientists and engineers, all sources of support, and scientists and engineers employed in the Federal Government are from National Science Foundation, **Employment of Scientists and Engineers in the United States, 1950–66,** NSF 68–30, table A-1. All other sectors based on derived estimates.

Little comment is required on the substantive aspects of table 21. The principal difference between this table and a similar table in chapter III is the addition of the R&D scientists and engineers estimated to be employed in the Federal Government. The estimates of federally supported employment are derived from the ratios developed in that chapter, but applied insofar as possible to 1965 data in order to maintain a rough temporal consistency. Clearly, the influence of Federal programs and funds on the utilization of scientists and engineers engaged in research and development is much greater than their influence on total scientist-engineer employment.

The field-of-science distribution shown in table 22 requires more extensive comment. The consolidation of the estimates of Federal use of scientists and engineers into broad fields of science was necessitated by the differences between employment and expenditure classifications. Detailed estimates of occupational employment are available, or can be derived for the Federal Government, private industry, universities and colleges, and for the independent nonprofit organization sectors. However, only data for universities and colleges on R&D expenditures are segregated by source of funds and reasonably well matched to the employment data in each of the detailed fields of science.[87] In all other sectors R&D expenditures are available, in published form at least, for three broad fields of science only. Expenditure data in all sectors for non-R&D functions are also available only on a broad field-

[84] Tabulations of Federal expenditures on science and technology in the National Science Foundation series, *Federal Funds,* show expenditures by field of science and by performer, but no cross-tabulation of these two dimensions. In the case of private industry and the universities and colleges, however, the surveys conducted in those sectors include sufficient information on total as well as R&D spending by source of funds to permit the estimates of employment developed in this study.

[85] National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–66,* p. 51. Only intramural spending provided the base and trend data.

[86] For example, in the independent nonprofit organization sector, annual costs per scientist or engineer man-year in January 1965 varied from $19,300 for the field of mathematics to $48,900 in the engineering sciences, as calculated from data in National Science Foundation, *Scientific Activities of Nonprofit Institutions, 1964* (NSF 67–17, 1967).

[87] It is assumed that the employment and expenditure data in a given sector match, though it is possible that an individual working as a physicist actually might be employed in another field of science.

Table 20. Federally supported employment as a percent of total employment of scientists and engineers, 1965
[In thousands]

Sector	Federally supported	Percent federal[1]	Percent of total federally supported
All sectors	393.4	29	100.0
Federal Government	132.1	100	33.6
Extramural sectors	261.3	21	66.4
Private industry	169.8	18	43.3
Universities and colleges	68.3	40	17.3
Independent nonprofit organizations	10.7	76	2.6
State and local governments	12.5	15	3.2

[1] Civilian only.
SOURCE: Table 6.

of-science basis. Thus, the problem of data lies more in identifying funding sources, expenditures and costs than in the area of occupational employment per se.

As a consequence of the foregoing data problems, the sectoral contributions to each of the fields-of-science are not strictly additive. In addition, data for the Federal Government sector relate to October 1966, while the estimated contributions of the other sectors are centered near January 1965. At most, it is possible to say that relative Federal effect is least in the engineering fields and greatest in the life sciences resulting in about 40 percent of 1965 employment of scientists and engineers in the latter.

Ideally, occupational detail to the level used in the interindustry transactions approach should be available for all sectors. At present, however, that approach provides only for estimation of federally supported occupational employment in the private industry sector. Comparable occupational and functional detail—and then only for the sciences, not engineering—is available only for one other sector, the universities and colleges. Should these difficulties be overcome, either by developing consistent technical coefficients and corresponding occupational patterns for other sectors or by developing and broadening the scope of surveys of science and engineering manpower in other sectors, the functional dimension of employment would be lost in using that approach. At present, research and development is treated in the input-output tables as a direct sale from the various producing industries to the purchasers in the final demand sectors, such as the Federal Government.[88] Consequently, no distinction can be made between personnel engaged in R&D and those engaged in other types of work. This would not be serious if it could be safely assumed that scientists or engineers in any given occupational category are functionally interchangeable. Limited information on this point, however, suggests otherwise.[89]

Applying the estimates

The critical test of an information system is the degree to which it can provide answers to significant questions within the system's domain. A few of the manpower information systems considered in this study apparently have been designed to meet specific needs, such as the Economic Intelligence System sponsored and managed by NASA and the Department of Defense. However, the majority of the systems are general purpose systems, even though concerned in each case with particular sectors. Consequently, they suffer from the practical limitations of such systems, including a lack of sufficient analytic detail,[90] while providing general answers to a variety of issues.

The information system synthesized in this study, despite sharing the limitations referred to above can answer some specific questions in the area of Federal program planning. Three have been chosen as a test of the data sources and the applicability of the approaches used. The answers provided are necessarily broad, and moreover, there is no measure of the degree of precision. Nevertheless, they may also serve to illustrate further needs for change or improvement in the information system. The questions to be answered, in order of increasing specificity, are:

1. Has utilization of scientists and engineers in Federal programs increased more rapidly than total employment in those occupations? Subsidiary to this question are related questions such as the nature of the change in the structure of the federally-supported scientist and engineer work force, such as the division between intramural and extramural employment, or

Table 21. Estimated employment of R&D scientists and engineers, by sector and source of support, 1965
[In thousands]

Sector	R&D scientists and engineers	Federally supported	Percent Federal
All sectors	504.3	280.6	56
Federal Government	65.7	65.7	100
Private industry	357.0	157.1	44
Universities and colleges	64.5	46.4	72
Independent nonprofit organizations	13.3	10.1	76
State and local governments	[1]3.2	[2]1.3	41

[1] Civilians only.
[2] Full-time equivalent employment.
SOURCE: NSF, **Employment of Scientists and Engineers in the United States, 1950–66**, table A-2, Page 22. Table II-4 ratios were applied to 1965 estimated employment.

[88] For a more complete explanation of the method of treating research and development, see *Projections 1970* (BLS Bulletin 1536, 1966), p. 38.

[89] For example, in 1966, 41 percent of employed scientists engaged in research and development held the Ph.D. degree; only 29 percent of those whose highest degree was the baccalaureate were so engaged. Calculated from National Science Foundation, *American Science Manpower, 1966*, (NSF 68–7, December 1967), table A–9, p. 70.

[90] This is not alone a matter of selective publication of survey results, but a question of design. Lack of coverage of costs and employment in the non-R&D scientific and engineering work force, in most sectors covered by the NSF surveys, is an example.

Table 22. Estimated utilization of federally supported scientists and engineers, by field of science and sector,[1] 1965

Sector	All fields	Engineering	Physical sciences[2]	Life sciences
Employment (in thousands)	1360.7	965.8	253.7	141.2
	Percent of total federally supported employment			
Federal Government[3]	9.3	7.7	12.3	14.4
Private industry	12.4	15.3	7.0	2.9
Universities and colleges	5.0	1.0	8.7	25.6
Independent nonprofit organizations	0.7	(5)	(5)	(5)
State-local government[4]	0.1	(5)	(5)	(5)

[1] Including employees of federally funded research and development centers administered by extramural sectors.
[2] Includes mathematics.
[3] October 1966 employment.
[4] R & D personnel only.
[5] Included in sector total.

SOURCE: Federal Government from NSF 68–30, tables A-1 to A-11.

between research and development and other activities. A satisfactory measure of the annual change in Federal demand can also be compared with the changes in the supply of scientists and engineers.

2. Given a major change in the structure of Federal programs but little change in the volume of expenditure, what are the implications for science and engineering manpower requirements? Specifically, how many scientists and engineers, would be released by a reduction in spending on the Viet Nam conflict, and how many could be absorbed by compensatory spending in other areas? What economic sectors are likely to be affected by postulated changes in program structure, and to what degree?

3. Given a change in the level of spending in a particular Federal program, what changes would be expected to occur in the detailed occupational requirements for scientists and engineers? At current rates of change in employment and in the aggregate supply of these occupations, can most of the displaced scientists and engineers expect to be absorbed, or will they be vulnerable to sustained unemployment?

Table 23. Estimated total and federally supported employment of scientists and engineers, by sector and character of work, selected years
[In thousands]

Sector	1954	1957	1964	1966	Compound annual rate of growth, 1954–66 (Percent)
All scientists and engineers	776.6	952.7	1,273.5	1,412.5	5.1
Federally supported	209.7	238.7	431.3	426.8	6.1
Federal Government[1]	79.7	90.1	126.4	134.1	4.4
Extramural	130.0	167.9	304.9	292.7	7.0
R&D scientists and engineers	237.1	302.3	490.5	520.5	6.8
Federally supported	127.8	162.1	342.1	346.1	8.6
Federal Government[1]	30.1	31.4	62.0	66.8	6.9
Extramural	97.7	130.7	280.1	279.3	9.1
Civilian labor force[2]	63,643	66,929	73,091	75,770	1.5
Nonagricultural employment[2]	53,898	58,123	64,782	68,915	2.0
Professional, technical and kindred workers[3]	5,588	6,468	8,550	9,322	4.3

[1] Civilian only.
[2] 16 years and over.
[3] 14 years and over.

SOURCE: Total employment and total R and D employment, NSF 68–30, table A-1; labor force, nonagricultural employment and professional, technical and kindred, U.S. Department Labor, Manpower Administration, **Manpower Report of the President,** April 1967, tables A-1, A-9.

Federal programs and growth of demand for scientists and engineers. Answers to the first question raised above were obtained by constructing a time-series built on the budget model described in chapter II. The employment estimates cover the period 1954–66, but are cruder than those developed in the earlier chapters. Data necessary to estimate employment in Federal programs by man-year expenditure estimates in particular sectors are not available on an annual basis, although for some sectors there are enough observations to permit more refined annual estimates by interpolation.

Table 23 shows the trends in the growth of employment of scientists and engineers and in the level and structure of federally supported employment in these occupations. Four different years were selected to exhibit these trends—the 2 terminal years, 1954 and 1966; 1957, which is the beginning for most sectors of systematic and probably more reliable employment data;[91] and 1964, which represents the period just prior to the Viet Nam buildup of defense program demand. The period 1957–64 also spans the buildup of the NASA manned lunar landing program.

Such a table permits analysis of changes in the pattern of utilization of scientists and engineers and its relationship to Federal programs. From the compounded annual growth rates, it is apparent that federally supported employment over the period 1954–66 has been growing nearly a fifth more rapidly than total employment. Growth has been especially rapid among R&D scientists and engineers, whose total employment growth rate substantially exceeds that of total science and engineering employment. Between 1957 and 1966, the proportion of R&D scientists and engineers rose from 32 to nearly 37 percent of total scientist-engineer employment. Of the increase in R&D scientists and engineers—about 218,000—federally supported employment is estimated at 184,000, or about 84 percent. Federally supported R&D employment was 98 percent of the increase in total federally supported employment. The table also indicates a relative shift in federally supported employment toward increased utilization of extramural scientists and engineers. Among R&D scientists and engineers in Federal programs, the rate of increase of those employed outside of the Federal Government was nearly a third greater than employment of so-called in-house personnel. By 1966, two of every three federally supported scientists or engineers were employed in the extramural sectors.

The findings summarized above could be extended to show the distribution of changes in Federal demand

[91] Data collected before 1957 on science and engineering employment are probably less reliable than in subsequent years. Hence, discussion is confined to the latter period.

Table 24. Supply and demand for scientists and engineers, 1958–66

[Numbers in thousands]

Year	Science and engineering degrees conferred[1]	Change in employment from previous year		Federally supported as percent of degrees conferred
		All sources of support	Federally supported[2]	
1958	96.9	42.4	20.9	21.6
1959	105.7	56.2	45.8	43.3
1960	110.1	46.0	8.1	7.4
1961	111.6	47.3	30.6	27.4
1962	116.2	59.7	32.6	28.0
1963	121.6	69.2	39.5	32.5
1964	135.6	46.6	15.1	11.1
1965	145.9	41.2	−1.7	—
1966	150.9	51.2	−2.8	—

[1] Bachelor's and first professional, masters' and doctoral degrees in engineering, agriculture, forestry, mathematics, biological science, physical sciences, and general sciences programs. Year indicates end of academic year.
[2] Civilian only.

SOURCES: 1958–63, degrees conferred from National Science Foundation, **Scientific and Technical Manpower Resources** NSF 64–28, tables V–12, V–15, and V–18, November 1964; 1964–66, from Office of Education, **Projections of Educational Statistics to 1976–77** (1967 ed.), tables 20, 21, 22.

for scientists and engineers by broad program categories. Since the interest here is primarily in method rather than substance, the necessary exercises were not performed. On the other hand, the method does not provide for estimates of employment changes in the occupational specialties, or even by broad field-of-science.

The pressures generated by changes in Federal programs and spending can also be evaluated by comparing the year-to-year changes in federally supported employment with the annual output of graduate scientists and engineers. Table 24 shows the results of such a comparison. The extent to which the annual reported output of the universities and colleges represents the effective supply cannot be ascertained, since some portion of the graduates at the bachelor's, first professional, and master's degree levels continue their formal education. Other science and engineering graduates in recent years have entered the Armed Services where, as indicated in chapter V, only about half (or less) may perform scientific or engineering tasks. The additional numbers who obtain scientific and engineering jobs by informal means, such as on-the-job training and upgrading, is practically unascertainable. On the other hand, the year-to-year changes in employment are exclusive of the changes in requirements resulting from retirement, deaths, or movement out of scientific and engineering fields.

Relative to the annual output of formally educated scientists and engineers federally supported demand appears from the estimates shown to vary greatly from year to year. On the average for the 9-year period shown in table 24, including 2 years in which federally supported demand showed an absolute decline, the annual Federal demand equaled almost a quarter of the earned degrees in the field. This proportion may understate the Federal effect on the effective supply of scientific and technical manpower, since substantial and increasing proportions of bachelor degree recipients in those fields continue their education instead of entering industrial, academic or public employment.[92] The decline in the last 2 years of the period may reflect the reduction in the space research program. Most of this reduction, in any case, occurred in the extramural sectors, which experienced a reduction of nearly 8,000 federally supported scientists and engineers between 1965 and 1966, mostly in the non-R&D extramural work force.

Changes in program structure and science and engineering manpower requirements. Major changes in the structure of Federal programs may effect comparably large short-term dislocations of manpower, even if the total volume of Federal program spending (in constant dollars) remains about the same. Scientists and engineers released from Federal programs that have been cut back will need to find employment in their occupations either in the strictly civilian economy or in expanding Federal programs. If, in fiscal terms, such programs offset reduced spending elsewhere, will their manpower requirements exceed or fall short of the numbers of released workers? This section is an effort to answer such a question.

Estimates of the savings resulting from a reduction in Viet Nam military spending and proposals for compensatory spending can be tested for their manpower implications in science and engineering. These estimates are based on those in the report of the Cabinet Coordinating Committee on Economic Planning for the End of Viet Nam Hostilities.[93] The Cabinet Committee estimates a fiscal year 1972 peace-and-growth dividend—a combination of reduced spending on Viet Nam and normal revenue growth—at $22 billion.[94] Since, however, there is no suitable method for projecting man-year costs of science and engineering employment, a substitute assumption is made that the spending on Viet Nam in fiscal year 1967 becomes immediately available for other uses. In addition, if it is assumed that there has been no rise in expenditures per scientist-engineer man-year between fiscal 1966 and fiscal 1967, the manpower implications of reduced defense spending and spending on new initiatives can be examined.

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[92] This is evidenced in part by the general decline in the proportion of bachelors' and first-professional to all degrees granted by institutions of higher education. According to one special study of June 1958 degree recipients and candidates, 47 percent of baccalaureate degree recipients in the natural sciences and mathematics and 22 percent of those awarded first degree in engineering enrolled in graduate schools for one term or more after receiving their degrees. National Science Foundation, *Two Years After the College Degree* (NSF 63–26, Washington, D.C., 1963), table 16, p. 29.

[93] In *Economic Report of the President,* (January 1969), pp. 181–212. The report is dated December 31, 1968.

[94] Ibid., pp. 199–201.

A decline in defense spending of more than $22 billion in fiscal 1967 would have reduced employment in the national defense programs by approximately 79,000 scientists and engineers. This estimate was obtained by dividing the reduction in expenditures by the implicit expenditure per man-year of defense scientist and engineer employment—approximately $276,000 in 1966 dollars. This employment reduction, accepting the ratios of intramural to total federally supported employment in defense, would consist of about 23,000 scientists and engineers employed in the Federal Government and 56,000 employed in other sectors.

Let it now be assumed that $22 billion will be spent to expand existing programs or to undertake "new initiatives" along the lines and in the magnitudes indicated in the Cabinet Committee's report.[95] Selection of the particular programs was governed by the availability of appropriate man-year expenditure ratios, and do not represent any preference regarding social and political priorities.[96] At the prices and costs assumed to prevail in fiscal 1967, new programs and program expansion in various nondefense areas would require nearly 39,000 more scientists and engineers than would be released by the reduction in Viet Nam spending. Nearly 4,000 of this increase in requirements, or 10 percent, would be added to the Federal Government's payroll if current ratios of intramural to total employment in each of the program areas remain constant. Requirements for the economy as a whole for scientists and engineers would exceed the numbers released because of the so-called "peace dividend" by almost 55,000, if the assumed reduction in taxes is converted into consumer spending. These estimates of requirements, of course, are conservative, since no allowance has been made to replace losses resulting from occupational mobility, retirement, and death during the post-Viet Nam transition.

The arithmetic of this exercise is as follows:

Program	Total expenditure (In billion dollars)	Cost per scientist or engineer	Employment change (In thousands)	Employed in Federal Government
Health, labor and welfare	15.1	141.8	106.5	18.3
Science and space research	1.0	72.0	13.9	2.3
Natural resource Development	1.4	175.0	8.0	7.2
Transportation	1.0	208.3	4.8	4.4
Surplus or tax reduction	3.5	227.3	–15.4	–5.1
All programs	22.0	–	117.8	27.1
Deduct:				
Defense				
Viet Nam	22.0	276.0	78.9	23.2
Net increase in Federal program Requirements	—	—	38.9	3.9

Various objections can be raised against the results of such an exercise. Most of the objections, however, relate to data gaps rather than to the logic involved, at least in the context of this study. For example, the wide difference in expenditure per scientist and engineer between the defense program and other programs implies that the latter generally are more labor-intensive. Although independent sources of data support this implication,[97] no source, of course, actually provides observed expenditure and related employment data on a Federal program basis. Objection also can be made against the implicit assumption that the manpower resources used in defense programs are transferable to other types of programs. Differences in the occupational and functional composition of various programs, however, cannot be accepted a priori as barriers to the mobility of scientists and engineers. An information system which also provides for measurement and appraisal of the sources of supply of such manpower, by occupation, industry and type of Federal program is clearly indicated.

Effect of changes in program expenditure. Changes in levels of support in particular programs may have significant economic and manpower implications, especially if reductions take place. Although several studies indicate that professional and technical workers generally fare better than other occupational groups in finding new jobs and maintaining pre-layoff wage and earning levels, in addition to the social costs, mass layoffs as the result of program changes can still result in considerable personal and family hardship.[98] In general, although work force characteristics play some part in the adjustment process, the more important factors affecting the effect of layoffs are controlable and permit advance planning to mini-

[95] Ibid., table 3, pp. 204–205.

[96] Originally it was hoped to locate back-up data on the industrial distribution of purchases in each of several new program areas. Such data would have made possible a superior estimate of the manpower implications, including occupational detail, through use of the interindustry transactions approach. Planning in most of these program areas, so far as could be ascertained, has not yet developed such data.

[97] In 1966, R&D funds from all sources—public and private—were $5,460 per employee in the aircraft and missiles industry as compared with $760 of company funds per employee in that industry. In nonmanufacturing industries, on the other hand, the respective R&D costs per employee were $410 and $120. National Science Foundation, *Research and Development in Industry,* 1966 (NSF 68–20), table 56, p. 70.

[98] Case studies of the labor market experiences of defense workers have been conducted under the sponsorship of the U.S. Arms Control and Disarmament Agency in the aircraft and missile industries. The findings of these studies have been summarized and subjected to intensive analysis in USACDA, *Reemployment Experiences of Defense Workers,* ACDA/F-113 (December 1968).

Table 25. Estimated employment of scientists and engineers per billion dollars of expenditures in defense programs, private industry, and Federal Government, 1965 or 1966

Occupation	Total defense	Private[1] Industry	Federal Government[2]
All scientists and engineers	3,370	2,230	1,140
Engineers, technical	2850	1980	870
Engineers, aeronautical	520	460	60
Engineers, chemical	70	50	20
Engineers, civil	260	100	160
Engineers, electrical	750	510	240
Engineers, industrial	260	230	30
Engineers, mechanical	510	370	140
Engineers, other	480	260	220
Natural scientists	520	250	270
Chemists	130	80	50
Agricultural scientists	10	[3]	[3]
Biological scientists	30	10	20
Geologists and geophysicists	30	20	10
Mathematicians	110	60	50
Physicists	130	50	80
Other natural scientists	80	30	50

[1] Department of Defense only; 1965.
[2] Department of Defense and Federal Government scientists and engineers in Atomic Energy Commission. Civilians only. October 1966.
[3] Less than 10.

mize adverse employment and earnings effects.[99] Knowledge of the levels and occupational distribution of the work force expected to be displaced by a program cutback would be useful in such planning.

Occupational coefficients developed along the lines of this study, can be used to illustrate the expected effect of a given reduction in defense spending on the employment of scientists and engineers. In that program area, however, such coefficients are available only for the private industry and Federal Government sectors, although these two sectors make up the bulk of defense employment in those occupations. In practice, reductions in spending would probably be governed by technical as well as political priorities. Consequently, the application of a reduction in expenditure would be concentrated in particular sectors rather than across-the-board, as assumed here.

Table 25 estimates occupational employment per billion dollars for scientists and engineers employed in the defense program in 1965. These estimates, as indicated, exclude employment in universities and colleges, independent nonprofit organizations, and State and local governments. Military personnel working as scientists or engineers also are excluded. However, given the estimated expenditures per man-year and the defense program structure prevailing in 1965 or 1966, the derived coefficients for the two sectors imply displacement (or growth) of about 3,400 scientists and engineers for each $1 billion reduction (or increase) in defense spending. The two sectors would be affected differently by changes in expenditure. The incidence of a general reduction would fall much more heavily on scientists and engineers employed in private industry than on employees of the Federal Government,[100] although not in each occupation.

Whether or not reductions in defense spending result in serious unemployment and other hardships, of course, depends on a number of factors. The magnitude of the reduction in spending, the rate of growth of employment in other programs or economic sectors, the rate of increase in the supply of the affected occupations, and the general state of the scientist-engineer labor market are among the more important factors to be considered in efforts to plan for such contingencies. This study, however, is limited to crude estimates of a few variables, mainly the trends in employment in the occupations and the corresponding occupational employment coefficients in table 25. By dividing the estimated average annual growth for the period 1950 to 1966 by the per-billion-dollar employment in each of several occupations, the size of a reduction in defense spending that could adversely affect employment and earnings opportunities can be inferred.

The results of such computations show that a reduction in the defense budget of approximately one quarter of its size in fiscal 1966 would slow the growth of scientist and engineering employment to nearly zero. For engineers alone, a $20 billion reduction would tend to freeze employment. In contrast, among chemists, the reduction would have to be nearly $50 billion to produce a similar result: for mathematicians the equivalent figure would be a little more than $40 billion.

Evaluation recommendations

General conclusions. The results of the exercises in estimation of the effect of Federal spending on the employment of scientists and engineers may be summarized in five broad conclusions and some recommendations.

The conclusions are:

1. A limited capability exists for measuring the employment effects of Federal programs in the field of scientific and engineering manpower. Given certain assumptions about the relationships between expenditures and employment, it was found possible to achieve plausible estimates of the employment magnitudes for the larger economic sectors, along functional lines and, to a probably lesser degree of accuracy, in terms of broad program categories. Estimation within program categories in terms of occupational specialization was least successful. In general, as the level of detail desired increases in any of the dimensions, the capability of the data sources for measurement of manpower tends to diminish.

[99] Ibid., pp. 220–221.

[100] In part, this is because the estimates of employment in the private sector include indirect as well as direct employment. No account has been taken of indirect employment generated by the government sector per se, although it probably would be quite small.

Table 26. Estimated percent of scientists and engineers on Federal work, by selected sources of estimates

Sector	Unit-cost estimate(a)	Input-output(d)	BLS-STP(c)	Census-NSF(b)	National Engineers Register(e)	National Scientists Register(f)	NSF-IHE Survey(g)
All functions and performers	28	30	(1)	(1)	[2]42.0	46.3	(1)
Non-R&D	12	(1)	(1)	(1)	(1)	35.4	(1)
R&D	49	(1)	(1)	(1)	(1)	57.9	—
Industry	44	(1)	45.6	44.0	—	(1)	—
Federal Government	100	(1)	—	—	—	—	—
Colleges and universities	72	(1)	(1)	(1)	—	(1)	[3]76.6

[1] Adjusted for not employed and no report.
[2] 1964.
[3] 1964–65.

SOURCES: (a) Tables II–4; (b) tables II–4, III–1; (c) U.S. Department of Labor, Bureau of Labor Statistics, **Survey of Scientific and Technical Personnel, 1966**; (d) National Science Foundation, **Research and Development in Industry, 1966**; (e) Engineers Joint Council, **Engineering Manpower in Profile, 1964**; (f) National Science Foundation, **American Science Manpower, 1966**; (g) National Science Foundation, **Reviews of Data on Science Resources,** (August 1966).

2. The foregoing conclusion is closely related to the general problem of measuring manpower requirements. Although measurement of Federal effect adds another—and extremely important—dimension, the basic problem is the measurement of the demand for scientists and engineers.

Until concepts and techniques of measurement of demand are further developed, the overall capability of the science manpower information system will remain weak.[101] Measures of demand or requirements for manpower must be directly related to measures of output such as total employment or the output of goods and services. In this study such a relationship could be established with reasonable certainty only for two broad aggregates of Federal program activity and expenditure, and then only for one economic sector. Estimates for other sectors at a gross level were made by assumptions that are plausible but not verifiable.

3. Data problems in estimating the effect of Federal spending on employment in science and engineering were encountered mainly in the measurement of output or expenditure. These problems, however, were encountered not because of a paucity of financial and expenditure data in most of the important sectors, but because of the absence of information on man-year expenditures specific to occupational groups, fields of science or engineering, and character of work. Indeed, rather than paucity, under present conditions there is an effective "loss" of manpower information in the process of estimating the effect of Federal spending on employment. Expenditures per man-year related both to funding sources and to some dimensions of employment and utilization of scientists and engineers were most adequate in the private industry and independent nonprofit organization sectors, less so or not at all in the university and college and government sectors, including the Federal Government.

Employment data, on the other hand, were reasonably adequate for most sectors, although the degree of detail varies among the sectors. Occupational employment measures are satisfactory in the Federal Government and private industry sectors, but only the latter sector relates the functional and occupational dimensions. A functional breakdown of employment of scientists and engineers in the Federal Government, expected to be available in the near future, should augment capability to measure that dimension. Occupational and functional measures of employment in the State and local government sector are virtually lacking. Scientists and engineers in the military services constitute an informational void.

4. For most practical purposes, measurement of the Federal employment effect is also inhibited by several conceptual problems. The most significant of these is the lack of a systematic, rationalized and operationally feasible conceptual framework for relating the physical services of Federal programs to measures of employment. The inability to penetrate this problem is a major failing of this study, although the general direction of a solution has been indicated.

To only a slightly lesser degree, the lack of coordination and integration of statistics on manpower and related analytical data is a conceptual problem in need of solution. The difficulties encountered in interrelating various sources of data, including manpower data purported to measure the same population of scientists and engineers, underscores a major conclusion of the Joint Economic Committee's Subcommittee on Economic Statistics.

> . . . further significant improvements in our statistical services depend upon a higher degree of integration and coordination of our statistical programs. Indeed, there are strong indications that this is the aspect of the statistical system where progress is needed most. . . . Nothing less than the quality of our public and private economic policies is at stake.[102]

The virtual absence for most sectors of information about man-year expenditures and output of scientists

[101] *A Study of Scientific and Technical Manpower,* Committee on Science and Astronautics, U.S. House of Representative, 86th Cong. 2d Sess., January 4, 1960, p. 33.

[102] Joint Economic Committee, Subcommittee on Economic Statistics, *The Coordination and Integration of Government Statistical Programs* (90th Cong. 1st Sess., 1967), pp. 1–2. A similar conclusion and recommendation was reached by the Killian Committee. National Academy of Sciences. Committee on Utilization of Scientific and Engineering Manpower, op. cit., p. 14.

and engineers engaged in non-R&D functions is still another conceptual weakness of the science manpower information system. Although our estimates indicate that the overall Federal impact among such scientists and engineers is relatively minor, in the aggregate they constitute more than 60 percent of total science and engineering employment. A significant shift in the structure of Federal programs would mean the need for more information about this group of scientists and engineers.

5. Given the present state of information on the employment of scientists and engineers, the preference for one or the other of the estimating approaches used in this study cannot be easily made. Either the budget or method of estimation or the interindustry transactions approach gives results that appear reasonable, although to cover all major dimensions of scientist and engineer employment in this study both approaches were necessary. In addition, as table 26 shows, the estimates of federally supported employment derived by these approaches match comparable estimates based on direct surveys in two of the larger sectors—industry and universities and colleges.[103] In part, this consistency is attributable to the common control totals,[104] although the effect of this factor on the estimates cannot be measured. The budget approach at present provides more insight into the sectoral and functional dimensions of the Federal employment impact, but is weak on the occupational and program dimensions. The interindustry transactions approach, in contrast, is somewhat stronger in these two respects, although the estimates of occupational employment diverge—substantially in some cases—from those provided in the time-series data for 1965. An explanation of the probable sources of these discrepancies is given in appendix D.

Under more ideal data conditions, the choice between the approaches would depend on the purposes of an analysis of Federal employment impact. Assuming a continuing flow of current manpower and related financial data, the budget-type approach would appear to be somewhat better suited to the analysis of short-term problems generated by changes in the levels of Federal program support. For the projection of manpower requirements in Federal programs, or for planning new initiatives and undertakings, the interindustry transactions approach seems more useful. With this approach better account can be taken of general economic trends that may affect future programs, such as the rate of technological change; indirect as well as direct manpower requirements can be estimated; and occupational employment patterns are readily available and adaptable to any given program "mix."

Recommendations for changes

1. The general strategy for improving the capability of the science manpower information system for measuring Federal employment impact should be based on the existing data sources and subsystems. No problems encountered in this study seems to compel consideration of an entirely new system of data on the employment of scientific and technical manpower. In addition, the various surveys and subsystems of employment and financial data already serve a variety of important interests and specialized groups of clientele. It is doubtful that a single, integrated system could meet all needs concurrently, including measurement and analysis of manpower requirements in Federal programs.

2. Substantial improvements can be made in the existing system, which will make measurement and analysis of Federal program requirements practically feasible. In general, much can be achieved by further integration and coordination of the relevant financial and employment systems. Careful attention should be given to the following:

a. A scheme of classification of fields of science and engineering common to all sectors and including both financial and employment data. It should be possible, for example, to bridge expenditure data reported in *Federal Funds* with employment and expenditure data in the various sectoral surveys of employment of scientific and technical personnel. Detailed occupational employment data should be collected in all sectors, but within a common conceptual framework of broader field-of-science groupings.

b. A common concept of reporting units for surveys of employment and expenditure in the private industry and business sectors. Although statistical arguments can be marshalled to support the company or enterprise concept used in studies conducted by the Bureau of the Census, technological and industrial developments strongly indicate that the establishment unit used by BLS may be analytically more rewarding.

c. Data collection centered on a common reference date. Employment and related data gathered by sectoral surveys should uniformly be related to the midpoint of the Federal fiscal year, that is, December or

[103] Note should be taken of the fact that the engineers' register and the scientists' register cover only their respective populations, while our estimates and the scientific, professional, and technical survey figures are composites of scientists and engineers. Using the input-output estimates for private industry and Federal Government data, estimates for scientists and for engineers are separately available. For those two subjects combined, federally supported employment of engineers is estimated at 24 percent; for scientists, the estimate is 27 percent.

[104] Both the Survey of Scientific and Technical Personnel in Industry and employment inverse generated from the input-output tables used *total* employment by industry as controls and/or data sources. Estimates of total employment are comparable to those collected in the establishment survey reported in *Employment and Earnings* (BLS Bulletin 1312–6).

January. Although a few industries are subject to strong seasonal patterns of activity, and others such as colleges and universities function on other than a calendar-year basis, so far as scientific and technical manpower is concerned the results would be little affected by a common date of survey or reference.

3. To further the recommendations in (2) above, serious consideration should be given to consolidation of some statistical programs in the field of science and technology. Specifically, the following possibilities should be considered and carefully evaluated:

a. Merger in one program of the Survey of Scientific and Technical Personnel, now conducted by the Bureau of Labor Statistics and the Survey of Industrial Research and Development, now conducted by the Bureau of the Census. These two programs cover virtually the same population in the largest sector of federally supported employment of scientific and technical manpower. The principal barrier to consolidation appears to be that occupational employment data are better collected at the establishment level, and financial and cost data are usually a central headquarters responsibility. No substantial reason, however, would bar collection of estimates of expenditures per man-year at the establishment level. Differentiation of these expenditures by function and field of science, as well as by source of support as indicated below, would help to develop useful employment estimators for various types of Federal programs.

b. The Economic Information System, which now covers a selected group of defense contractors, should be terminated. This program, at least on the employment side, duplicates in part the coverage of the STP program. Its main function appears to be to provide information on the regional distribution of defense contract employment, but in other important respects—occupation, character of work, employment costs, and especially, Federal support of employment—EIS either provides no information or employment estimates which may contain a substantial bias. The regional distribution of employment in defense and other Federal programs can easily be ascertained from the establishment-based STP data.

4. Further improvements in the data base can be made by efforts to fill gaps and lacunae in the present system. Among those to which early consideration should be given are:

a. Occupational and related employment characteristics of engineers. At present, detailed occupational specialization in the engineering profession is available only from the decennial census and from the records of the Federal Civil Service. It is recognized that definitions of engineering occupations may be more difficult than definition of the various scientific specialties, although the latter are also not free of ambiguity. The problem, however, is more a matter of the level of education or training than a question of job content and the nature of the services provided. Special studies in selected industries may help to resolve the difficulties in surveying engineering employment on an establishment basis.

b. Increased attention should be given to establishing appropriate definitions and concepts for measuring employment and requirements in the social and behavioral sciences. These occupations were excluded from consideration in this study, and financial and expenditure data were adjusted (accordingly) to maintain consistency with the current BLS-NSF definition of scientists and engineers. Continued omission of the social and behavioral sciences, however, may not be warranted. Political and social developments indicate that Federal and private activity will increasingly develop toward greater utilization of those professions.

c. Classification and measurement of personnel serving in the Armed Forces as scientists and engineers should be explored. Scientists and engineers in uniform may constitute an additional 4 to 5 percent of federally supported employment of scientists and engineers, but they are not accounted for in either the estimates of total or Federal science and engineering employment. An effort to measure such personnel in this study failed mainly because the Department of Defense lacks an information system adequate for measuring employment and utilization of uniformed scientists and engineers. Differences in the classification schemes among the four service branches appear to be a major obstacle.

5. This study's greatest obstacle and most conspicuous failure proved to be the development of employment estimates in a detailed program framework. A solution to this problem will depend, first, on the development of a conceptual framework and corresponding measures of program activity or output. This part of the problem will necessarily have to be solved cooperatively between the operating agencies, the Bureau of the Budget, and the agencies responsible for the collection and analysis of data on scientific and technical manpower. Once such a framework becomes available, the second part of the problem will be to establish a means of collecting and analyzing data on federally supported employment of scientists and engineers.

It is proposed that benchmark employment and related financial and output data in major Federal programs be collected by periodic surveys. The collection of such data should be the direct responsibility of the dominant agencies in each of the designated program fields, for examples, the Department of Defense, the Department of Health, Education, and Welfare and so on. However, the surveys should be under the general guidance and direction of the National Science Foundation to ensure uniformity of manpower, field-of-science, occupational and functional concepts as well as sectoral coverage and survey dates. Should such benchmark surveys be developed and established on a coordinated basis with the present sample surveys, further elaboration of the details of Federal support would not appear to be necessary. Indeed, under such circumstances, a case might be made for eliminating this issue from employment surveys now on an annual or biennial cycle, such as the STP. Experience in the general behavior of occupational employment relationships indicates that a survey cycle of 3, or even 5, years may be sufficient to meet most of the needs of the Government for such data.

6. Further experimentation should be made with the interindustry transactions approach to investigate the manpower implications of various Federal programs, especially in areas of proposed Federal activity. The major effort needed here will be to estimate bills-of-goods for each such program. Additional study also may be needed to evaluate the validity of the occupational patterns.

7. For manpower planning in the fields of science and engineering, there is a need for reliable estimates of total requirements. In addition to changes in the requirements generated by Federal programs, occupational coefficients reflecting changes resulting from replacement needs—retirement, out-mobility, and death—should also be developed.

8. Although not an objective of this study, for the purposes of measuring Federal employment effect, work on various aspects of the behavior of the labor market for scientists and engineers should be encouraged. Among the topics in need of further investigation and analysis are the industrial, occupational and functional mobility of such workers; the sources of supply of labor to the scientific and engineering occupations; the effects of earnings on changes in the supply and demand for scientific and technical manpower; and the relationship between training and education and the utilization of scientists and engineers. Such studies would not only be valuable in understanding the labor market, but essential for analysis and interpretation of data on federally supported employment in this field.

Appendix A. A Note on Program Planning and Manpower Requirements

This study investigates the degree to which manpower requirements were being estimated as part of the Planning-Programming-Budgeting System in various Federal Government agencies. The investigation was neither exhaustive nor systematic; approached were only a few agencies to which the researcher was directed because these agencies were thought to have made some progress toward projecting manpower requirements as an integral part of the PPBS exercise.[1]

PPBS is an effort to achieve efficiency in the allocation of resources in government programs.[2] Its proponents visualize its concepts and techniques as substitutes in the public sector for the price and profit indicators used in investment decisions (or long-term planning) in the private, market-oriented sector. Charles Schultze has described PPBS as an effort to replace the practice of incremental budgeting or planning with a scheme that reviews and evaluates the costs and benefits of government programs as a whole.[3] PPBS was established on a Government-wide basis by a Presidential directive in August 1965. Manpower requirements and costs are among the more important elements to be evaluated under the system.

Our investigation of the manpower aspect of PPBS may be briefly summarized in the following conclusions:

1. Manpower planning as an integral component of PPBS has made relatively little progress in the agencies surveyed, although there is general interest in the development of this component.
2. Assessment and costing of future manpower requirements in most Federal agencies is limited to intramural employment. A number of agencies, for example, the Bureau of Mines, concern themselves principally with manpower planning as an internal management or personnel administration tool. Agencies which have made more inclusive projections of professional and technical manpower requirements in their areas of responsibility vary with respect to the integration of projected requirements into their PPBS programs. Mostly, these agencies have education and training of scientific and technical manpower as a substantial responsibility—for example, AEC, NASA, the National Institutes of Health, and the Department of Agriculture. Only a few, notably AEC, have attempted to include projected manpower requirements in their PPBS memorandums.
3. Lack of an adequate information system on manpower inputs, especially in the extramural sectors, may be a significant barrier to progress in Federal manpower planning under PPBS.
4. Another imporatnt limiting factor is a shortage of personnel in the Federal Government with skill and experience to develop the operating concepts and manpower information systems required for PPBS.

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[1] Among the agencies visited or contacted by telephone were the Department of Agriculture, the Department of Defense, the Department of the Interior, the Department of Labor, the Department of Health, Education, and Welfare, the Federal Aviation Administration, the National Aeronautics and Space Administration, the Atomic Energy Commission, and the Bureau of the Budget. Discussion in each case was quite general and open-ended, although several agencies generously provided documents relating to their manpower information systems.

[2] There is a growing literature on PPBS. In addition to the Government's own studies (see, for example, *Budget of the United States, Special Analysis, Fiscal Year 1970,* Pt. 4, pp. 253–273), there are several good introductory explanations of objectives and techniques. See David Novick, ed., *Program Budgeting,* (Rand Corporation, Santa Monica, California, 1965); Charles L. Schultze, *The Politics and Economics of Public Spending* (Washington, D.C., The Brookings Institution, 1968), especially chapter 2, pp. 19–34; and Edward Sussna, "Planning, Programming, and Budgeting Systems—A New Approach to Government Spending," *Pittsburgh Business Review,* May 1968.

[3] Schultzer, op. cit., p. 23.

Appendix B. Estimated total employment and employment attributable to Federal purchases of goods and services, by source of procurement and industry,[1] 1965

[In thousands]

Industry titles	Total employment	Federally supported		
		Total	Department of Defense	All other Federal Government
All industries	62,325.4	3,220.4	2,079.2	1,141.3
Livestock and livestock products	1,936.1	17.6	8.3	9.3
Other agricultural products	2,395.2	41.1	14.1	27.0
Forestry and fishery products	109.1	12.7	1.9	10.8
Agricultural, forestry and fishery services	220.3	9.9	1.6	8.4
Iron and ferroalloy ores mining	293.5	2.4	1.5	0.9
Nonferrous metal ores mining	56.5	13.2	4.1	9.2
Coal mining	147.6	7.8	4.3	3.5
Crude petroleum and natural gas	307.2	20.0	15.8	4.2
Stone and clay mining and quarrying	988.2	5.4	2.6	2.8
Chemical and fertilizer mineral mining	17.8	1.2	0.6	0.6
New construction	2,556.4	118.7	35.1	83.6
Maintenance and repair construction	1,114.0	103.0	53.7	49.3
Ordnance and accessories	225.9	185.6	101.7	83.8
Food and kindred products	1,795.1	18.1	6.7	11.5
Tobacco manufactures	87.0	0.6	0.4	0.2
Broad and narrow fabrics, yarn and thread mills	603.5	14.9	11.8	3.2
Miscellaneous textile goods and floor coverings	115.4	3.4	2.3	1.1
Apparel	1,541.7	10.9	5.6	5.3
Miscellaneous fabricated textile products	162.5	6.7	4.1	2.6
Lumber and wood products, except containers	622.2	32.3	17.2	15.2
Wooden containers	37.5	2.5	1.4	1.0
Household furniture	332.5	11.8	8.5	3.3
Other furniture and fixtures	133.6	5.6	1.7	3.9
Paper and allied products, except containers	435.0	15.7	11.8	3.9
Paperboard containers and boxes	198.8	15.8	6.0	9.8
Printing and publishing	1,046.1	33.7	29.5	4.1
Chemicals and selected chemical products	407.3	36.9	15.7	21.2
Plastics and synthetic materials	194.8	23.1	6.6	16.5
Drugs, cleaning, and toilet preparations	225.5	8.8	3.2	5.6
Paints and allied products	64.9	8.6	3.0	5.6
Petroleum refining and related products	182.6	12.2	10.2	2.0
Rubber and miscellaneous plastics products	469.6	21.0	18.7	2.3
Leather tanning and industrial leather products	35.8	13.1	5.4	7.7
Footwear and other leather products	327.7	4.0	3.8	0.1
Glass and glass products	170.3	7.5	6.6	1.0
Stone and clay products	440.2	17.5	14.1	3.4
Primary iron and steel manufacturing	917.8	65.5	51.6	13.9
Primary nonferrous metals manufacturing	357.6	60.9	33.7	27.2
Metal containers	70.6	16.4	1.0	15.4
Heating, plumbing and structural metal products	432.7	11.7	10.9	0.7
Stampings screw machine products and bolts	318.8	45.9	24.1	21.8
Other fabricated metal products	418.7	33.6	20.1	13.5
Engines and turbines	90.3	20.8	7.7	13.1
Farm machinery and equipment	138.6	4.8	1.8	3.0
Construction, mining and oil field machinery	174.8	4.2	4.0	0.3
Materials handling machinery and equipment	76.2	5.0	3.0	2.0
Metalworking machinery and equipment	316.1	25.5	24.2	1.3
Special industry machinery and equipment	195.6	12.6	3.1	9.5
General industrial machinery and equipment	252.1	17.4	15.9	1.5
Machine shop products	209.7	37.7	33.0	4.8

Appendix B. Estimated total employment and employment attributable to Federal purchases of goods and services, by source of procurement and industry,[1] 1965—Continued

[In thousands]

Industry titles	Total employment	Federally supported		
		Total	Department of Defense	All other Federal Government
Office, computing and accounting machines	190.1	20.0	14.2	5.8
Service industry machines	111.7	5.1	3.2	1.9
Electric industrial equipment and apparatus	355.4	42.9	30.8	12.1
Household appliances	159.1	4.0	2.6	1.4
Electric lighting and wiring equipment	169.5	15.5	9.7	5.8
Radio, television and communication equipment	549.3	226.5	181.0	45.5
Electronics components and accessories	306.1	98.7	71.2	27.5
Miscellaneous electrical machinery and supplies	100.4	8.8	6.1	2.7
Motor vehicles and equipment	842.9	18.2	13.5	4.7
Aircraft and parts	624.2	446.9	373.0	73.9
Other transportation equipment	268.5	48.2	45.4	2.7
Scientific and controlling instruments	258.9	43.9	27.1	16.8
Optical, ophthalmic and photographic equipment	128.0	14.3	12.8	1.5
Miscellaneous manufacturing	451.8	12.3	6.7	5.6
Transportation and warehousing	2,695.1	183.5	145.8	37.6
Communications: except broadcasting	771.5	41.5	24.5	17.1
Radio and television broadcasting	108.1	6.1	3.4	2.7
Electric, gas, water and sanitary services	633.0	32.8	18.9	13.9
Wholesale and retail trade	15,224.0	202.6	120.2	82.4
Finance and insurance	2,582.6	50.0	31.3	18.7
Real estate and rental	767.0	12.8	8.1	4.7
Hotels; personal and repair services, except auto	2,747.6	82.2	36.5	45.7
Business services	2,161.6	122.7	70.5	52.2
Research and development	101.7	52.5	38.7	13.7
Automobile repair and services	493.3	13.5	6.3	7.2
Amusements	706.0	13.5	8.7	4.8
Medical, educational and nonprofit organizations	4,851.0	176.1	95.3	80.8

[1] SIC equivalents of industry groups defined in Bureau of Labor Statistics, **Projections 1970**, Bulletin 1536 (Washington, D.C., 1966) table IV–1 p. 58.

Appendix C. Estimated federally supported extramural employment of scientists and engineers by State and local governments, selected occupations, 1965

Occupation	Total employment	Federally supported	Percent federally supported
All scientists and engineers	70,795	7,653	10.8
Engineers, technical	59,754	6,147	10.3
Aeronautical	627	94	15.0
Chemical	2,633	357	13.6
Civil	22,618	1,476	6.5
Electrical	8,766	999	11.4
Industrial	4,955	594	12.0
Mechanical	9,155	1,048	11.4
Metallurgical	1,612	228	14.1
Mining	862	232	26.9
Other	8,849	1,167	13.2
Natural scientists	11,041	1,506	13.6
Chemists	5,011	561	11.2
Agricultural scientists	1,127	98	8.7
Biological scientists	827	76	9.2
Geologists and geophysicists	1,163	208	17.9
Mathematicians	1,221	155	12.7
Physicists	1,001	129	12.9
Other natural scientists	588	52	8.8

Appendix D. Discrepancies between time series employment estimates and occupational matrix estimates

Discrepancies are noted between estimates of occupational employment in private industry published in *Employment of Scientists and Engineers in the United States,* National Science Foundation, NSF 68–30 and those reported in the BLS occupational matrix used in chapter IV of this study. These discrepancies are shown in the following table:

Interindustry

Occupation	*Matrix*	*Time Series*	*Difference*
Engineers	863,657	785,800	77,857
Natural scientists	224,743	175,300	49,443
Chemists	92,927	83,900	9,027
Agricultural scientists	22,038	6,100	15,938
Biological scientists	23,394	9,400	13,994
Geologists and geophysicists	19,405	13,400	6,065
Mathematicians	25,708	26,500	–792
Physicists	22,387	15,300	7,087
Other natural scientists	17,264	20,200	–2,930

The discrepancies may occur for a variety of technical reasons, primarily differences in industry and worker classification schemes used in the two studies. Differences may also be due to the different survey methods. Time Series data are based on employer enumeration; occupational matrix data was developed from the U.S. Census of Population which is based on individual employer enumeration. In the Time Series, all government employees are enumerated under the government sector. In the matrix concept, government employees, except those in public administration functions, are classified in the appropriate industry category for activities commonly carried on also by the private sector. These differences can be better illustrated perhaps by using agricultural scientists as an example.

About 6,100 agricultural scientists were employed in private industry in 1965 according to the Time Series (STP). The occupational matrix shows 22,038 agricultural scientists, a difference of almost 16,000 (15,938). Over one-half of all agricultural scientists shown in the matrix are in the agriculture, forestry, and fisheries sector of the economy. Most are in the forest products industry. Under the matrix concept, the agriculture, forestry and fisheries sector included over 36,000 government workers in 1960. Some of these workers are agricultural scientists. In the matrix, foresters and conservationists are included in the totals for agricultural scientists. Therefore, some Federal "agricultural" scientists show up as being employed in the agricultural, forestry, and fisheries sector under the matrix concept. In the Time Series, on the other hand, all Federal Government workers are included in the Federal Government sector. In 1965, about 15,500 agricultural scientists were employed by the Federal Government. State and local governments employed an additional 5,600 agricultural scientists.

Appendix E. Estimated scientists and engineers employed in the Federal Government selected occupations, by Program October, 1966

Occupation	All programs	National Defense[1]	International affairs	Space	Agriculture	Natural resources	Commerce[2] and transport	Housing and development	Health Education and Welfare	Veterans affairs	Other programs
Total Scientists and Engineers	131,087	61,492	3,097	13,646	15,605	16,097	9,098	554	5,803	1,527	4,168
Engineers, Technical	76,832	47,024	759	8,877	2,403	7,745	4,890	549	1,457	506	2,622
Engineers, aeronautical	8,898	3,076	....	5,478	....	....	324	....	....	....	20
Engineers, chemical	1,358	853	14	9	67	349	15	....	44	....	7
Engineers, civil	18,606	8,942	395	62	1,522	3,686	2,247	292	946	104	410
Engineers, electrical	18,323	13,101	75	1,110	181	1,472	1,572	6	111	24	671
Engineers, industrial	2,089	1,860	9	22	19	42	25	1	2	13	96
Engineers, mechanical	8,796	7,424	15	186	62	357	132	20	78	34	488
Engineers, metallurigical[3]	811	510	....	226	1	53	11	....	2	1	7
Engineers, mining	434	52	4	....	16	303	....	....	1	....	58
Engineers, other	17,517	11,206	247	1,784	535	1,483	564	230	273	330	865
Natural Scientists	54,255	14,468	2,338	4,769	13,202	8,352	4,208	5	4,346	1,021	1,546
Chemists	8,135	2,685	156	119	939	1,027	351	....	1,956	624	278
Agricultural scientists	14,739	214	1,767	2	10,005	2,562	1	1	153	....	34
Biological scientists	6,933	932	336	76	1,851	2,203	19	....	1,176	326	14
Geologists, geophysicists	2,638	738	28	....	132	1,311	236	....	128	....	65
Mathematicians	4,109	2,708	8	643	48	146	340	4	164	10	38
Physicists	5,763	4,228	6	381	38	201	745	....	83	48	33
Other natural scientists	11,938	2,963	37	3,548	189	902	2,516	....	686	13	1,084

[1] Excludes Selective Service.
[2] Commerce and FAA.
[3] Materials engineering.

Source: National Science Foundation, **Scientific and Technical Personnel in the Federal Government, 1966,** NSF 68–16, April 1968.

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