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THE PROSPECTIVE MANPOWER SITUATION FOR SCIENCE AND ENGINEERING STAFF IN UNIVERSITIES AND COLLEGES, 1965-75.

BY- MILLS, THOMAS S. CAIN, ROBERT W.
NATIONAL SCIENCE FOUNDATION, WASHINGTON, D.C.

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REPORTED IS A NATIONAL SCIENCE FOUNDATION (NSF) STUDY OF SCIENTIFIC MANPOWER. THE PRINCIPAL OBJECTIVES WERE THE ESTABLISHMENT OF TRENDS AND THE ILLUMINATION OF FACTORS THAT SIGNIFICANTLY AFFECT FUTURE REQUIREMENTS FOR SCIENCE AND ENGINEERING ACADEMIC STAFF IN HIGHER EDUCATION. THE DATA WERE DERIVED FROM SURVEYS COMPLETED BY NSF, NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL, U.S. OFFICE OF EDUCATION, AND OTHERS. SOME TRENDS INDICATED FOR THE 1965-75 PERIOD ARE (1) TEACHING AND RESEARCH WILL BE THE PRIMARY ACTIVITIES IN HIGHER EDUCATION, AND WILL LARGELY DETERMINE STAFF NEEDS, (2) THE EMPLOYMENT OF SCIENCE AND ENGINEERING STAFF WILL NEARLY DOUBLE AS A RESULT OF EXPANDING ENROLLMENT AND RESEARCH NEEDS, (3) THE REQUIREMENTS FOR DOCTORATES IN THESE FIELDS WILL GREATLY EXCEED THE SUPPLY AVAILABLE IN THE EARLY PART OF THE PERIOD, (4) BY THE MIDDLE OF THE DECADE THE GROWING NUMBER OF DOCTORATES WILL CAUSE THE SITUATION TO IMPROVE, ALTHOUGH THE PROPORTION OF SCIENCE STAFF HOLDING THE DOCTORATE DEGREE AT THE END OF THE DECADE WILL NOT BE AS HIGH AS THE 1965 RATIO. THE APPENDIXES PRESENT DATA CONCERNING (1) THE ESTIMATED SCIENTIFIC MANPOWER REQUIREMENTS FOR TEACHING AND RESEARCH, (2) SCIENCE AND ENGINEERING STAFF SUPPLY AND DEMAND FOR PERSONS HOLDING DOCTORATE DEGREES, AND (3) ESTIMATED PRODUCTION OF PEOPLE HOLDING DEGREES IN SCIENCE AND ENGINEERING FIELDS. THIS DOCUMENT IS ALSO AVAILABLE FOR $0.30 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (DS)

science & engineering STAFF in universities and colleges

1965-75

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the prospective manpower situation for science and engineering STAFF in universities and colleges, 1965-75

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Foreword

EXPERIENCE WITH THE RAPID GROWTH of American science and technology during the past two decades has increasingly pointed to scientific and technical manpower as the key resource required for an effective national scientific effort. Most of the other resources needed for the development of this national program, while probably equally important, can be made available in a relatively short time. However, the development of scientific manpower requires many years and thus calls for continuous attention and analysis if we are not to experience major scientific manpower problems in the future.

This report constitutes one of the many National Science Foundation studies of scientific manpower. It was prepared by Thomas J. Mills and Robert W. Cain of the Office of Economic and Manpower Studies, H. E. Riley, Head. Extensive discussions and comments from many individuals, both within the Foundation and from other U.S. institutions, have greatly contributed to the effectiveness of this study.

The numerical projections in this report are based on a series of assumptions, some of which may prove to be incorrect. Furthermore, the interaction of supply and demand constitutes a very complex process, which is not sufficiently well understood to be taken explicitly into consideration in quantitative projections. Thus, the most important aspect of this report is not the development of specific numbers, but rather the establishment of trends and the illumination of some of the factors that significantly affect future requirements for academic staff.

CHARLES E. FALK
Planning Director
National Science Foundation

MAY 1967

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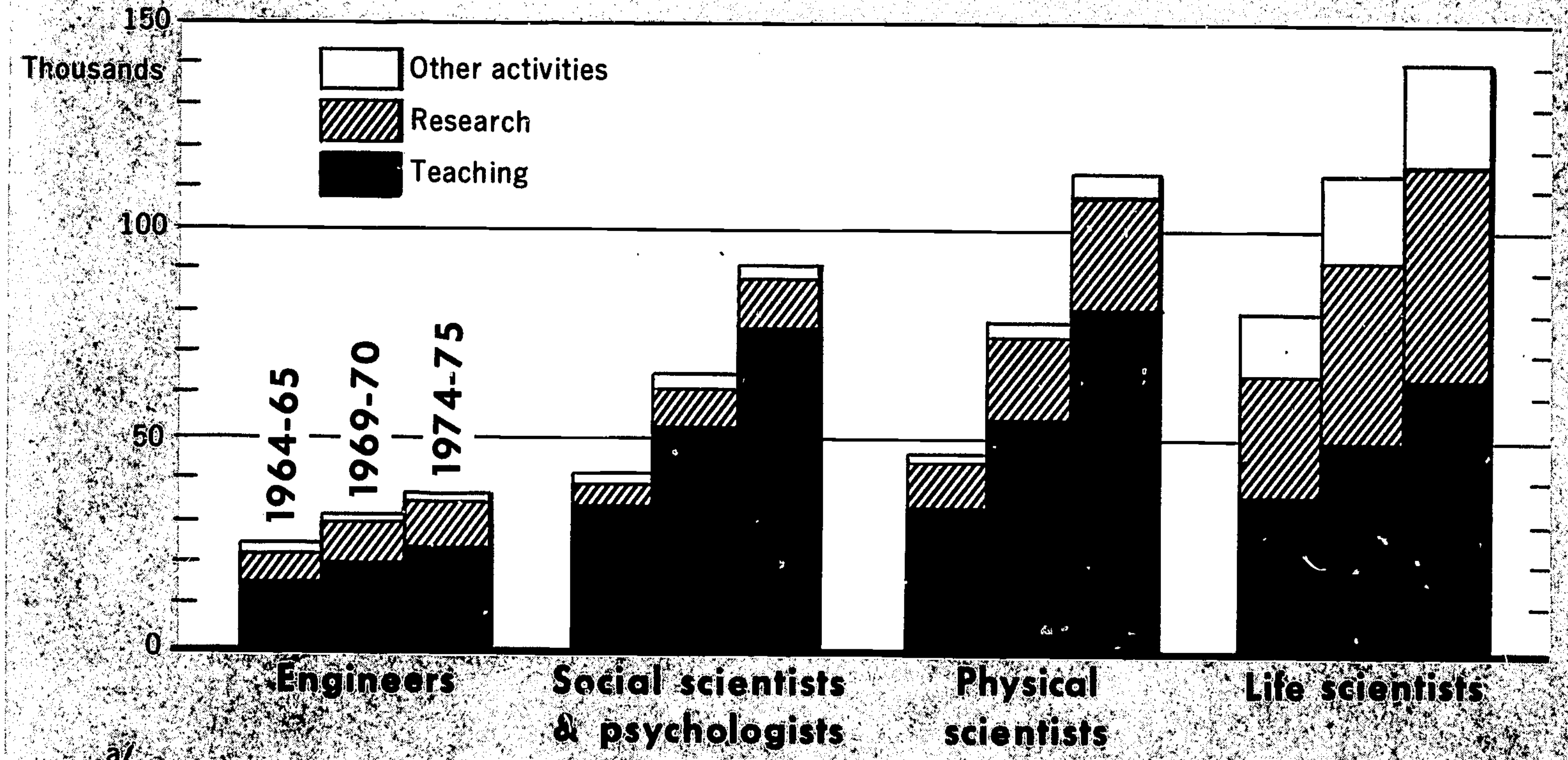
TEACHING AND RESEARCH are the principal activities of higher education and will largely determine staff needs between 1965 and 1975. Employment of science and engineering staff is expected to approximately double as a result of needs arising from expanding enrollments and research. In addition to recruitments to fill these needs, universities and colleges will have to replace normal attrition (death, retirement, or transfer to other employment). The requirements for doctorates in these fields will greatly exceed the probable supply available to universities and colleges in the early part of the period. By the early 1970's the growing numbers of doctorates will approximate the academic requirements, and the situation will improve. However, the proportion of science staff holding the doctorate degree (Ph.D., Sc.D., etc.) will decline for several years after 1965 and, even at the end of the decade, will not be as high as the 1965 ratio.

Requirements for Science and Engineering Staff[a] in Universities and Colleges

Selected years



[a] Full-time equivalents

Source: National Science Foundation (tables C-1, D-1, and E-1)

Introduction

DURING THE PERIOD since World War II, the Federal Government has been increasingly concerned with the need for expanding and improving our education system and, in particular, for enhancing the Nation's capabilities for higher education in the sciences and engineering. Substantial amounts of Federal funds in forms such as research grants and contracts, grants for buildings and equipment, and fellowships for graduate study have been made available to universities and colleges and to their students during this period. Thus, in fiscal year 1965, Federal obligations for the support of academic science and other educational activities in universities and colleges totaled $2.3 billion.[1]

The growth in graduate education has resulted in an increased supply of potential college teachers with doctoral degrees. At the same time, however, the increase in population and in the proportion seeking higher education has raised requirements for college staff. An assessment of the current and prospective balance between supply and demand for teaching staff in the institutions of higher education is a necessary ingredient in plans for the future development of our educational system.

The Federal programs for defense, space exploration, peaceful uses of atomic energy, medical research, and the solution of major social problems are heavily dependent upon the availability of highly qualified scientists and engineers. This need focuses attention on the demand-supply situation for these skills in our educational system, especially as it affects the capacity to provide the trained scientists and engineers required to meet our future demands.

This report examines the prospective demand and supply situation for university and college staff in the natural and social sciences, psychology, mathematics, and engineering during the decade 1965-75.[2] The analysis excludes Federal Contract Research Centers administered by universities and colleges. Furthermore, the report mainly takes a quantitative approach to the supply and demand situation for staff. An attempt was made to assess the qualitative factor inherent in the differences among individuals in terms of levels of degrees attained. However, other qualitative factors such as teaching experience or research specialization were not assessed. At this stage the report can be considered to show only first approximations. More basic data and more study are required to fill in details, to evaluate the assumptions used, and to consider the implications of alternatives.

In this brief analysis, an attempt has been made to review and utilize where applicable the results of other studies in the field. Appendix H lists the principal studies that have been concerned with manpower supply and demand in universities and colleges, including methodologies for assessing supply-demand relationships.

Among the components needed for the construction of a set of projections are basic data describing the current situation, data extending back over time that can serve to reveal significant trends and stable relationships, and clearly defined assumptions reflecting what appear to be the most likely external factors affecting the

1 National Science Foundation, *Federal Support for Academic Science and Other Educational Activities in Universities and Colleges, Fiscal Year 1965*, NSF 66-30. Washington, D. C. 20550, 1966.

2 Years shown throughout the remainder of the report represent academic years ending in June; e.g., 1965 is academic year 1964-65.

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future trends of the phenomena to which the projections refer.

Each of the assumptions used in the analysis is only one of a number of possible alternatives. Other assumptions, perhaps equally logical and defensible, may lead to significantly different conclusions. For example, any appreciable modification in the ratio of science degrees granted to science teaching staff greatly influences the requirements level. On the other hand, the assumption relating to the attrition rate is relatively insensitive; only a substantial revision ot this rate has a significant effect upon projected doctoral needs.

Requirements

THE PRINCIPAL DETERMINANTS of science and engineering manpower requirements for universities and colleges are student enrollments, the level of research performed, and attrition losses from death, retirement, or transfer to other employment. A 1965 NSF survey of university and college research expenditures and employment provides benchmark data on the numbers of scientists and engineers engaged in teaching, research, and other activities.[3] (See appendix A.) In the absence of satisfactory estimates of future enrollments in science and engineering, calculations of undergraduate teaching loads were derived from the projections made by the Office of Education of baccalaureate degrees awarded in science and engineering.[4] Graduate teaching requirements were similarly estimated on the basis of projections of doctorates and master's degrees in these fields provided by the Commission on Human Resources and Advanced Education.[5] (See assumption *1* on page 5 and appendix B.)

Teaching

Some educators argue that the student-teacher ratio (or degrees granted-teacher ratio) will necessarily increase with the growth of enrollments and potential shortages of teachers. Others point to the growth of graduate education and specialized courses as leading to a smaller ratio. This analysis is based upon maintaining the approximate ratios of science and engineering degrees to FTE[6] teachers in these fields found in 1965 as a reasonable point of departure for a first approximation of requirements. (See appendix C for estimates of teaching requirements.) The ratios were calculated separately for four broad fields and undergraduate and graduate levels, and they take into account both the requirements of the degree-granting institutions and the nondegree schools, such as junior colleges. Such constant ratios may be more appropriate for science courses, which require laboratory and other small group instruction, more generally than other fields. (See assumption *2* on page 5.)

Research

After teaching, the principal activity of scientists and engineers in universities and colleges is the performance of research, and the level of such activity is a major determinant of staff needs. The 1965 NSF benchmark survey reported 55,000 FTE scientists and engineers and $1.87 billion involved in research (excluding staff and expenditures in the Federal Contract Research Centers administered by universities). According to this source, research staff are more than one-quarter of all scientists and engineers in universities and colleges in FTE

[3] Since more than 95 percent of all research and development performed by universities and colleges consists of basic and applied research, the term "research" is used throughout the report to denote these activities.

[4] U. S. Office of Education, *Projections of Educational Statistics to 1975–76* (1966 Edition), OE–10030–66. Washington, D. C. 20402: Supt. of Documents, U. S. Government Printing Office.

[5] These projections are preliminary figures, obtained through the courtesy of the Commission and prepared by Donald S. Bridgman, consultant to the Commission. They are being revised and, therefore, may differ from those finally released by the Commission.

[6] Many university science and engineering staff members engage in teaching, research, or other activities part time. The concept of full-time equivalent (FTE) conventionally designates the number of full-time staff it would take to expend the same total effort in a given activity. The number consists of those engaged in the activity full time plus the sum of the part-time fractions in the activity (including employed graduate students).

numbers, and are almost one-half as numerous as those in teaching.

Research staff requirements are projected as keeping in step with teaching requirements by maintaining the same 1965 relationship through 1975. This method recognizes the close relationship between teaching and research, but does not take account of the argument that the present level of academic research is insufficient and that the quality of teaching should be improved by greater exposure to these activities. Appendix D shows projected annual requirements for science and engineering staff in research. (See assumption *3* on page 5.)

Appendix D also provides data on several different levels of research funds with implied manpower requirements for 1975. These statistics permit alternative estimates of research manpower requirements based on a methodology that assumes different levels of research expenditures.

Other Activities

Another component of the requirements for science and engineering manpower is the number engaged in administrative, managerial, and service activities at academic institutions. This group is often ignored in demand estimates, although in the 1965 NSF survey it accounted for an addition of 12 percent to the total of FTE scientists and engineers engaged in teaching and research. (See appendix E.) The field-by-field percentages of "other" staff to the totals in teaching and research are projected to 1975 according to the ratios found in 1965.

Attrition

The annual attrition rate for academic scientists and engineers appropriate for projection purposes has been one of the greatest causes for differences in the estimation of gross requirements. Death, retirement, and net transfer rates used in other studies have ranged from a total replacement rate of about 1.5 to 5 or 6 percent per year. Since limited evidence reported by the National Register of Scientific and Technical Personnel for academic scientists with doctorates implies a slight net gain in supply because of transfers to higher education employment, a 2-percent total annual attrition rate was assumed, which agrees reasonably well with other estimates for death and retirement rates alone. Appendix F provides further information on the attrition rates used in other studies. (See also assumption *4* on page 6.)

Summary

The net requirements for scientists and engineers in higher education institutions are considered dependent upon enrollments, as measured by science and engineeering degrees awarded; research performed, as measured by a constant percentage of the requirement for teachers; and other activities, generally of an administrative nature taken as a percentage of the total in teaching and research. Gross requirements also take into account a replacement rate for deaths, retirements, and transfers to nonacademic employment.

These gross requirements over the decade, expressed in terms of full-time equivalents and numbers employed ("head count" of full-time and part-time staff), are shown in table 1.

Table 1. ESTIMATED REQUIREMENTS FOR SCIENCE AND ENGINEERING[a] STAFF IN UNIVERSITIES AND COLLEGES[b] FOR ALL ACTIVITIES, 1964–65 TO 1974–75

(In thousands)

Academic year	Full-time-equivalent number: Total[c]	Full-time-equivalent number: Excluding graduate students[d]	Number employed[e]
1964–65	192.6	164.0	189.6
1965–66	224.8	191.4	220.7
1966–67	247.6	210.9	242.5
1967–68	252.2	214.8	246.4
1968–69	263.7	224.6	257.4
1969–70	285.9	243.5	279.1
1970–71	303.4	258.4	295.7
1971–72	323.9	275.8	315.0
1972–73	340.1	289.6	330.1
1973–74	358.9	305.6	347.7
1974–75	381.2	324.6	368.9

[a] Natural and social sciences, mathematics, psychology, and engineering.
[b] Excludes Federal Contract Research Centers administered by these institutions.
[c] Full-time and part-time staff and employed graduate students—those employed full time plus the full-time equivalent of those employed part time.
[d] The 1965 ratio of graduate students to the total FTE number (about 15 percent) was used to obtain projected estimates of FTE excluding graduate students.
[e] "Head count" of full-time and part-time staff only; does not include employed graduate students. See appendix E for calculation.

Source: Appendix table E-1.

Supply

Importance of Doctorates

The critical component of the supply of scientists and engineers for higher education is the number of doctorates available. Approximately 50 percent of university and college teaching and research staff hold the Ph.D. degree, although considerable differences exist among both academic fields and types of institutions. Staff in many science and engineering fields appear to have higher ratios of doctorates, according to Office of Education surveys,[7] although several have lower ratios, notably medical scientists (as defined in the 1965 NSF survey) who frequently have professional degrees, such as the M.D. or D.D.S. For this reason, supply of and requirements for medical scientists have been estimated separately in this study. A doctorate ratio of 50 percent was assumed for engineering and all fields of science except medical. A ratio of 25 percent doctorates for medical scientists was used, based on limited evidence at hand. The weighted ratio for all science fields combined is less than 45 percent. Overall, probably around 30 percent of science and engineering staff hold the master's degree, leaving over 25 percent with miscellaneous professional or baccalaureate degrees. Many of those in the latter groups are at some stage in securing further graduate training and eventually will obtain doctorates (Ph.D, Sc.D., etc.). According to the National Academy of Sciences-National Research Council survey of earned doctorates, approximately 20 percent of the science and engineering doctorates are full-time employees of universities and colleges at the time the degree is awarded.[8]

The analysis focuses on the doctorate supply as being the important determinant of whether needs can be met without substantial deterioration of the quality of academic staff. Additional nondoctorates can be expected to be available generally from the substantial number of master's and professional degree holders currently graduating at a rate exceeding 60,000 per year.

Available Doctorates

Continuation of at least the base doctorate ratio (25 percent for medical scientists and 50 percent for all other fields) for scientists and engineers (excluding graduate students) in higher education is assumed to be necessary to maintain quality of the staff. The additional supply of doctorates available for academic institutions is composed of newly awarded recipients of that degree plus doctorates of earlier years who are attracted to the universities and colleges after a period of employment in industry, government, or other sectors.

The numbers of doctorate awards by field have been projected through 1975 by the Commission on Human Resources and Advanced Education and the U.S. Office of Education. The Commission estimates are selected as perhaps more truly representative of science and engineering fields, since they are closely linked to recent baccalaureate degree trends. (See appendix B for the projected doctorates.)

The proportion of science and engineering doctorates anticipating first employment in

[7] U. S. Office of Education, *Teaching Faculty in Universities and Four-Year Colleges, Spring 1963*, OE-53022 and *Staffing American Colleges and Universities*, OE-53208, 1966. Washington, D. C. 20402: Supt. of Documents, U. S. Government Printing Office. Both these surveys were made of samples of institutions or staff; therefore, the precise percentage of total science and engineering staff with doctorates is unknown.

[8] Unpublished tabulations from the NAS-NRC survey of earned doctorates for the eight years through 1965.

higher education after receiving the degree is reported by the NAS–NRC survey of earned doctorates. Over the past eight years through 1965, the percentage of new science and engineering doctorates expecting first employment in universities and colleges has ranged from 46 to 52 percent and averaged 49 percent. These statistics include both teaching and research staff as well as postdoctoral fellowship holders. In other words, over the past several years, the commitment to universities and colleges has generally been about 50 percent of the new doctorates. However, this average conceals less favorable rates in chemistry (32 percent), earth sciences (40 percent), and engineering (39 percent) and more favorable ratios in the social sciences (68 percent) and mathematics (65 percent). (See assumption *6* on page 6.)

Information on the extent to which "older" doctorate recipients return to academic employment is scarce. National Register data [9] for a substantial group of doctorate holders over several recent years seem to show a considerable gross movement between different types of employment, but the net result is only a slight plus for universities and colleges. Any substantial net gain from the older doctorates is believed to be unlikely through 1975, given the competitive requirements of industry, private research organizations, and the Federal Government.

Another element is the number of noncitizens receiving doctorates. This number has been increasing and now accounts for about 15 percent of doctorates awarded in the sciences and more than 20 percent of those in engineering, according to the National Research Council survey of earned doctorates (see footnote 8). The extent to which noncitizens may be counted as part of the supply available to universities and colleges is a complex question. Favoring such employment is the fact that these institutions generally have less rigid citizenship requirements than Government or private industry. About one-third of the noncitizen Ph.D.'s expect to be employed outside the United States, as do a small percentage of the citizens. In all, only 5 to 10 percent of the new science and engineering doctorates expect foreign employment upon receipt of the degree. However, many of the noncitizens who remain here initially may return to their native lands after additional research and teaching experience and so be lost to the academic work force in this country. In the absence of better evidence that the proportion of foreign doctorates will change, it seems reasonable to conclude that the present 60 to 70 percent of the noncitizen doctorate holders will continue to find domestic jobs for at least their first post-degree employment. (See assumption 7 on page 6.)

[9] Published in U.S. House of Representatives, Select Committee on Government Research, *Impact of Federal Research and Development Programs,* Study No. VI, 88th Cong., 2nd sess., pp. 74–75. Washington, D. C. 20402: Supt. of Documents, U.S. Government Printing Office, 1964.

Summary

According to estimates provided by the Commission on Human Resources and Advanced Education, the number of doctorates awarded in science and engineering is expected to increase from about 11,000 in 1964-65 to more than 28,000 in 1973-74. The indicated supply of additional doctorates available for higher education employment, assuming continuance of the 50-percent recruitment rate for new doctorates, will range from about 5,500 for 1965-66 to 14,100 for 1974-75, as shown in table 2.

TABLE 2. DOCTORATES AWARDED AND DOCTORATES AVAILABLE TO HIGHER EDUCATION IN SCIENCE AND ENGINEERING FIELDS,[a] 1964–65 TO 1974–75

(In thousands)

Academic year	Doctorates awarded	Doctorates available for employment [b]
1964–65	11.0	—
1965–66	12.1	5.5
1966–67	13.4	6.1
1967–68	15.0	6.7
1968–69	16.8	7.5
1969–70	18.5	8.4
1970–71	20.2	9.3
1971–72	22.6	10.1
1972–73	25.2	11.3
1973–74	28.2	12.6
1974–75	—	14.1

[a] Natural and social sciences, mathematics, psychology, and engineering.
[b] 50 percent of the previous year's awards.

Source: Appendix tables B-1 and G-1.

Assumptions

ANY PROJECTION depends on certain assumptions, either expressed or implied. For this analysis an attempt has been made to specify a set of realistic assumptions. By its nature, however, any assumption is only one of a number of alternatives. Others, perhaps equally logical and defensible, may lead to significantly different conclusions.

The development of projections of social phenomena involves the assessment of many variables too numerous to deal with individually. The practice of singling out the most important variables for individual treatment and assuming fixed parameters for others is usually followed in order to reduce the exercise to manageable proportions. However, it is always recognized that assumptions are important, sometimes the most important, factors determining the final results.

Several of the assumptions underlying this analysis have already been explicitly stated. The more important of these and other implicit assumptions are enumerated here for clarification and possible substitution of alternatives.

1) The continuance of recent trends in higher education enrollments and degrees in the sciences and engineering through 1975 is assumed. Projections of degrees in science made by both the Office of Education and the Commission on Human Resources and Advanced Education assume that the 1960-65 experience for the proportion of enrollments and degrees to the college-age population will generally be valid through 1975. (See appendix B.) Revision in deferment policies used by the Selective Service System and the recently enacted "Cold War GI Bill" (Veteran's Readjustment Benefits Act of 1966) may be influential factors in future graduate enrollments; however, it is too early to gauge their possible importance.

2) The ratio of science and engineering degrees to FTE teachers in these fields is assumed to be an appropriate norm to determine requirements for teaching. This is not a completely satisfactory assumption, since it may not fully take into account changes in service course loads, the suitability of the 1965 ratio for extrapolation purposes, the course changes in degree requirements, shifts between fields before award of degrees, the timing of requirements in relation to the timing of the award of degrees, etc. However, in the absence of enrollment data by fields, this ratio seems to provide a reasonable substitute. The 1965 NSF data for science and engineering teachers by field, distributed by level (undergraduate and graduate) according to the Office of Education study,[10] provide the basis for the degree-teacher ratios used in this projection of teaching requirements. To account for the timing deficiencies, a 2-year lag was provided in the undergraduate teacher-degree ratio. That is, estimated baccalaureates for 1967 are related to the 1965 teaching staff.

3) The ratio of FTE scientists and engineers engaged in research by field to those engaged in teaching derived from data in the 1965 NSF study is assumed to be appropriate for the following decade. Basing projected research staff needs upon this assumption has the advantage of not requiring a projection of price levels, which is implicit in projections based upon research expenditures. This assumption implicitly associates the level of academic research with the level of student enrollments in a given field.

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10 U.S. Office of Education, *Teaching Faculty in Universities and Four-Year Colleges, Spring 1963, op. cit.*

In order to assess the effect of an alternative assumption, another projection of staff needs was based on a level of $4.5 billion for research expenditures in universities and colleges to be reached by 1975. This model further assumed that the 1965 average of $34,000 in research expenditures per scientist or engineer would escalate at an average of about 3.5 percent per year, reaching about $46,000 by 1975. These calculations resulted in projected needs of FTE research staff in 1975 only 8 percent lower than that developed from the model based upon maintaining constant the ratio of research staff to teaching staff.

4) The assumed attrition rate of 2 percent per year has already been mentioned and is further discussed in appendix F. This rate is a judgment on the conservative side in terms of replacement of staff lost largely through death or retirement. The 2-percent rate makes little or no allowance for any net loss to other employers. A low rate can be supported on the basis that the average age will decline with recruitment of large numbers of younger staff members.

5) Implicit in the projected growth of doctoral degrees is an assumption that financial resources for facilities, faculty, and student support will continue to be provided to accommodate the larger numbers desiring graduate school education. In other words, resources must be invested to provide the institutional basis for this activity. Currently, practically all graduate students in the natural sciences and engineering receive support generally in the form of teaching and research assistantships, fellowships, etc., about one-half of them through Federal funds.

6) Salaries and nonpecuniary benefits are now apparently attractive enough to place the universities and colleges generally in a favorable recruitment situation as compared with competitive employment opportunities in industry and government. While higher education in the past has fallen behind in the competition, it is assumed that, through 1975 at least, the universities and colleges will continue to remain competitive enough to enable them to recruit up to 50 percent of new doctorates in the sciences and engineering.

7) It is further assumed that noncitizens will continue to account for about 15 percent of all science and engineering doctorates awarded and that about two-thirds of them will be available for domestic employment in at least their first jobs (about this many have been available over the past several years). The reverse flow of doctorates from foreign countries are not explicitly accounted for. In spite of the considerable publicity given to the "brain drain," the number of immigrant doctorate-level personnel is not large (estimated at not more than 2 percent) in terms of the numbers of degrees granted by U.S. institutions.

8) Finally, there is the assumption underlying the entire analysis that meaningful projections of staff requirements and supply can be made, even though extremely complex relationships and variables affect the results. This view holds that the recent trends have enough inherent stability to reveal continuing truth if properly interpreted.

Findings

1) The requirements for university and college staff (teaching, research, other), based on the methodology and assumptions stated, amount to 381,000 scientists and engineers on a full-time-equivalent basis in 1975 as compared with 193,000 in 1965. Since an actual number of persons ("head count") is required for estimating recruitment needs, the FTE data were translated into the numbers of individuals required. Also, because the analysis is directed toward the doctorate supply, employed graduate students were excluded from this translation. Thus, the total number of individuals (excluding graduate students) needed for teaching, research, and other activities in 1975 is 369,000, or 179,000 more than in 1965. (Appendix E summarizes requirements by activity and converts from FTE to numbers of individuals, based on relationships found in the 1965 NSF survey.)

2) Provision must also be made for the replacement of staff members leaving the field through death, retirement, or transfer to other employment. Based upon an attrition rate of 2 percent per year (see appendix F), there will be an additional staff requirement of 56,000 over the 10 years, an average of 5,000 to 6,000 per year.

3) On the assumption that the additional staff recruited (excluding graduate students) should hold the doctorate in at least the same proportion as the staff employed in 1965 (25 percent for medical scientists and 50 percent for all other fields), the indicated annual requirement for science and engineering doctorates ranges from a low of less than 5,000 to a high of about 16,000 over the period 1965-75. (See appendix G for the computation of requirements for expansion, replacement, and doctorates annually through 1975.)

4) The indicated supply of additional science and engineering doctorates available for universities and colleges, assuming continuance of the 50-percent recruitment rate for new doctorates, will range from about 5,500 for 1966 to 14,100 for 1975.

5) Under the assumptions given, the proportion of science and engineering staff holding the doctoral degree will decline for several years after 1965 and, even at the end of the decade, will not be as high as the 1965 ratio. The analysis was not carried beyond 1975, but it appears that after this date the situation will improve as available doctorates increase sharply and requirements become relatively stable.

6) The conclusions reached in this analysis tend to conform generally to those obtained in recent studies by Cartter and Folger.[11] Both of these studies anticipate a tight supply situation for doctorates early in the 1965 to 1975 decade and after that substantial improvement, even to the possibility of surplus doctorates for university and college employment. The Foundation has marshalled certain data not previously brought to bear on this matter and may have provided some further insights into the prospective manpower supply situation in universities and colleges.

[11] Allan M. Cartter, "Future Faculty Needs and Resources." *Improving College Teaching, Aids and Impediments*, 49th Annual Meeting, American Council on Education, 1966; and John K. Folger, "The Balance Between Supply and Demand for College Graduates," *Journal of Human Resources* II:2, spring 1967.

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Implications

1) The finding that the proportion of science and engineering staff with doctorates will decline for several years after 1965 develops from the sharp increase in requirements and the lag in doctorate production. This overall decline obscures the differential impact upon different fields and types of institutions. For example, the 40 percent of new engineering doctorates currently recruited to academic situations, if continued, will exceed the 50-percent requirement for new engineering faculty with the doctorate and permit an improvement in the relatively low percent (about 39) of existing engineering teaching staff with that degree. Conversely, both the physical and biological sciences are seen to deteriorate in terms of doctorates held by new recruits. The social sciences will about hold their own. A flexibility exists in the system which frequently permits the engineering doctorate to teach physics or mathematics, the chemist to teach chemical engineering, the physicist to teach astronomy, and the like. Individuals trained in one field cannot usually teach in a different one without a deterioration in the quality of teaching.

2) The several types of higher education institutions do not now possess the same proportions of doctorates on their science and engineering staffs. For example, relatively few doctorates are engaged in junior college teaching, but many are in public and private universities. The liberal arts school science staff covers a wide range. The general implication of the supply picture through 1975 is that the heaviest impact will probably fall on the junior colleges, the liberal arts institutions, and those universities with relatively small research programs, each of which will be at competitive disadvantage with well-financed private and large State universities. Furthermore, some institutions (e.g., junior colleges) may well also be at a disadvantage in attracting individuals holding master's degrees.

3) Under the given assumptions, the staff requirements are linked to degrees granted in the sciences and engineering. The relative staff involvement in teaching and research found in 1965 is extrapolated to 1975. The implied 1975 expenditures level for academic research and development can be roughly calculated at $3.6 billion, assuming no increase in the 1965 average of $34,000 in research expenditures per scientist or engineer. If, however, research costs per scientist or engineer are assumed to increase an average of only 3.5 percent per year, then the 1975 academic R&D cost will total about $4.9 billion, compared with $1.9 billion in 1965.

4) The importance of supporting science and engineering education, particularly at the graduate level, at a continuing rate consistent with the growth in enrollments cannot be overstated. The past growth has been accompanied by large increases in fellowships, research funds, equipment and facility outlays, etc. and probably could not have occurred without them. Extrapolation of past enrollment trends implies comparable increases in resources devoted to education in these fields. The magnitude of the implied 1975 current expenditures for support of education in these fields can be partially shown in estimated amounts spent for instruction and departmental research. In 1975, these costs are calculated at $3.2 billion (compared to $1.6 billion shown in the 1965 NSF survey), assuming that there will be no increase in the amount of expenditures per staff position in teaching. If a modest increase averaging only 2 percent per year in this ratio is assumed, the 1975 expenditures will total about $3.8 billion. Indirect costs (overhead) allocable to instruction and departmental research could add an amount of approximately one-third of the basic expenditures.

5) In spite of the apparent trend described above, this result is by no means inevitable. If this trend is recognized as only a direction in which higher education is now traveling, the destination might yet be changed. Certain actions, if occurring early within the decade, would tend to void or adjust the situation. Among them are those attributes that tend to make university employment more desirable than heretofore; i.e., improved salaries, greater prestige, liberalization of fringe benefits such as sabbatical and research leaves, smaller teaching loads, etc. Teaching aids, curriculum improvement, use of part-time staff and technicians, capital expenditures, and other actions may improve staff effectiveness and permit higher student-faculty ratios. Requirements for personnel and the available supply have been considered independently in this report. In practice, supply and requirements react against each other. Though universities and colleges employ a larger share of all doctorates (Ph.D., Sc.D., etc.) than any other sector, competition exists and, of course, the supply is available to all sectors. The findings of this study indicate that, by the end of the 1965-75 decade, universities and colleges will be in a favorable position with respect to the employment situation for doctorates; however, during the decade there will be considerable strain between requirements and supply. The great unknown is the share of all doctorates to be employed by the nonacademic sectors, especially private industrial concerns. A moderate increase in requirements for doctorates from nonacademic employers may not greatly affect the academic market. On the other hand, a substantial decline, which might result from a dampening of R&D activities in private industry, could greatly improve the supply situation for universities and colleges.

APPENDICES

APPENDIX A

The NSF Survey of Scientific Activities at Universities and Colleges, 1965[1]

The number of scientists and engineers in universities and colleges, January 1965, used in these projections, came from NSF's university and college survey, conducted February-December 1965. The 1,942 institutions receiving the questionnaires represent those listed in the U.S. Office of Education's *Directory, Higher Education, III, 1963-64*, except 250 independent schools of art, music, theology, law, and other specialized institutions unlikely to have science and engineering programs. A total of 1,600 institutions (82 percent) returned usable questionnaires. The 342 nonresponding institutions are engaged in relatively small programs in science and engineering fields. Survey staff made estimates for these institutions, using Federal agencies' reports of R&D funds provided to educational ininstitutions; the academic institutions' own bulletins, catalogs, and financial reports; and other data from U.S. Office of Education and the American Council of Education. These same sources also permitted estimates for nonresponse items. An error believed to be less than 1 percent of national aggregates may exist as the result of estimates made for nonresponse. Survey estimates are, of course, always subject to error attributable to respondent failure to interpret and apply survey instructions uniformly.

The 1965 survey provided many of the benchmarks used in this analysis. In particular, the survey is the source of the numbers of full-time and part-time staff and employed graduate students in science and engineering and the FTE numbers—total (193,000), in teaching (118,000), in research and development[2] (55,000), and in other activities (20,000)—for January 1965, the mid-point of academic year 1964-65. It also provided basic information on personnel according to fields of science and engineering and the estimated total R&D expenditures of $1.87 billion for the year 1965. These data refer to universities and colleges, excluding Federal Contract Research Centers administered by these institutions.

Similar surveys of scientific activities at universities and colleges were conducted by the National Science Foundation in previous years.[3]

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[1] Preliminary findings from the survey may be found in National Science Foundation, *Reviews of Data on Science Resources*, No. 9, "Resources for Scientific Activities at Universities and Colleges, 1964," NSF 66–27. Washington, D. C. 20402: Supt. of Documents, U.S. Government Printing Office, August 1966.

[2] Since more than 95 percent of all research and development performed by universities and colleges consists of basic and applied research, the term "research" is used throughout the report to denote these activities.

[3] National Science Foundation, *Scientific Research and Development in Colleges and Universities—Expenditures and Manpower, 1953-54*, NSF 59–10, December 1958; *Scientific Research and Development in Colleges and Universities—Expenditures and Manpower, 1958*, NSF 62–44, December 1962; and *Scientists and Engineers in Colleges and Universities, 1961*, NSF 65–8, December 1964. (Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office.)

APPENDIX B

Estimated Production of Baccalaureate, Master's, and Doctorate Degrees in Science and Engineering Fields, 1956-75

Earned degrees conferred by U.S. universities and colleges at the baccalaureate, master's, and doctorate levels increased spectacularly over the past decade and will continue to increase substantially over the next decade. The rising college-age population and the greater support of higher education by both public and private agencies promise a tremendous increase in enrollments at both undergraduate and graduate levels. Baccalaureate degrees in science and engineering fields increased more than 80 percent between 1955-56 and 1964-65 (130,000 to 237,000) and are expected to increase

TABLE B-1. ESTIMATED BACCALAUREATE PRODUCTION IN SCIENCE AND ENGINEERING FIELDS, 1955–56 TO 1974–75

(In thousands)

Academic year	Total	Physical sciences [a]	Engineering	Life sciences [b]	Social sciences and psychology
1955–56	130.3	16.3	26.3	42.8	44.9
1956–57	144.4	18.5	31.2	45.6	49.2
1957–58	158.1	21.3	35.3	47.6	53.9
1958–59	167.2	24.5	38.1	48.6	56.0
1959–60	172.8	27.5	37.8	48.9	58.6
1960–61	174.5	28.6	35.9	48.8	61.2
1961–62	182.5	30.5	34.7	49.8	67.4
1962–63	196.2	32.4	33.5	53.4	76.9
1963–64	219.1	36.2	35.2	56.7	91.0
1964–65	237.3	39.0	36.8	61.9	99.7
1965–66	238.7	40.5	35.8	60.3	102.1
1966–67	256.1	45.2	37.8	63.0	110.7
1967–68	304.8	56.0	42.7	72.8	133.4
1968–69	337.1	64.2	45.3	78.3	149.2
1969–70	338.7	66.2	43.7	76.8	151.9
1970–71	347.8	69.6	43.4	77.0	157.8
1971–72	366.6	75.4	43.4	78.0	167.3
1972–73	384.3	81.6	44.3	80.3	178.0
1973–74	409.3	88.8	45.0	84.7	190.9
1974–75	428.1	95.9	45.7	83.6	202.9

[a] Includes mathematics.
[b] Includes health fields (medicine, dentistry, pharmacy, etc.), agriculture, forestry, biological sciences, and one-half of sciences, general program.

Note: Detail may not add to totals because of rounding.

Source: U. S. Office of Education, *Projections of Educational Statistics to 1975-76*, OE-10030-66; 1955-56 to 1964-65 actual and 1965-66 to 1974-75 projected.

to 428,000 in 1974-75, according to estimates made by the U.S. Office of Education.[4] Master's degrees awarded in these fields, after more than doubling between 1955-56 and 1964-65 (18,000 to 42,000), are expected to rise another 150 percent by 1974-75 to 109,000, according to estimates of the Commission on Human Resources and Advanced Education.

Doctorates granted nearly doubled between 1955-56 and 1964-65 (5,700 to 11,000) and are expected to increase even more—nearly tripling to over 30,000 by 1974-75, according to estimates of the Commission.

The projections for the next decade assume a continuation in the trend of increased support to students and institutions in higher education—for faculties, fellowships and traineeships, institutional grants, and research activities.

[4] U.S. Office of Education, *Projections of Educational Statistics to 1975–76,* OE 10030–66. Washington, D. C. 20402: Supt. of Documents, U.S. Government Printing Office, 1966.

TABLE B–2. ESTIMATED MASTER'S DEGREE PRODUCTION IN SCIENCE AND ENGINEERING FIELDS, 1955–56 TO 1974–75

(In thousands)

Academic year	Total	Physical sciences [a]	Engineering	Life sciences [b]	Social sciences and psychology
1955–56	18.1	3.5	4.7	4.5	5.4
1956–57	19.4	3.7	5.2	4.7	5.8
1957–58	21.6	4.3	5.8	5.0	6.5
1958–59	23.7	4.7	6.8	5.4	6.8
1959–60	25.4	5.2	7.2	5.6	7.4
1960–61	27.9	6.0	8.2	5.6	8.1
1961–62	30.7	6.6	8.9	6.1	9.1
1962–63	33.8	7.5	9.6	6.5	10.2
1963–64	37.7	8.2	10.8	7.2	11.5
1964–65	42.4	9.2	12.0	7.9	13.3
1965–66	47.7	11.0	13.1	8.9	14.7
1966–67	52.5	11.9	14.1	9.9	16.6
1967–68	56.8	12.8	14.8	10.5	18.7
1968–69	62.5	13.8	15.9	11.8	21.0
1969–70	70.6	15.5	17.3	13.6	24.2
1970–71	77.6	17.1	18.9	14.2	27.4
1971–72	84.8	18.2	20.4	16.2	30.0
1972–73	91.7	19.7	22.2	16.8	33.0
1973–74	98.2	21.2	24.2	18.1	34.7
1974–75	108.5	22.5	26.1	21.4	38.5

[a] Includes mathematics.

[b] Includes health fields (medicine, dentistry, pharmacy, etc.), agriculture, forestry, and biological sciences.

Note: Detail may not add to totals because of rounding.

Source: Commission on Human Resources and Advanced Education; 1955-56 to 1964-65 actual and 1965-66 to 1974-75 projected.

TABLE B-3. ESTIMATED DOCTORATE[a] PRODUCTION IN SCIENCE AND ENGINEERING FIELDS, 1955-56 TO 1974-75

(In thousands)

Academic year	Total	Physical sciences[b]	Engineering	Life sciences[c]	Social sciences and psychology
1955-56	5.7	1.9	0.6	1.4	1.8
1956-57	5.7	1.9	.6	1.5	1.7
1957-58	5.7	1.9	.6	1.5	1.7
1958-59	6.1	2.1	.7	1.4	1.8
1959-60	6.5	2.1	.8	1.7	1.9
1960-61	7.0	2.3	.9	1.7	2.1
1961-62	7.7	2.5	1.2	1.8	2.2
1962-63	8.6	2.9	1.4	1.9	2.4
1963-64	9.7	3.0	1.7	2.2	2.7
1964-65	11.0	3.6	2.1	2.5	2.8
1965-66	12.1	3.9	2.4	2.5	3.2
1966-67	13.4	4.3	2.8	2.8	3.6
1967-68	15.0	4.7	3.2	3.1	4.1
1968-69	16.8	5.1	3.6	3.6	4.6
1969-70	18.5	5.5	3.9	4.0	5.1
1970-71	20.2	5.9	4.3	4.4	5.7
1971-72	22.6	6.4	4.6	5.1	6.5
1972-73	25.2	7.0	5.1	5.8	7.3
1973-74	28.2	7.7	5.6	6.6	8.3
1974-75	30.5	8.3	6.2	6.8	9.2

[a] Includes Ph.D., Sc.D., and similar degrees; excludes professional degrees such as M.D. or D.D.S.

[b] Includes mathematics.

[c] Includes health fields, agriculture, forestry, and biological sciences.

Note: Detail may not add to totals because of rounding.

Source: Commission on Human Resources and Advanced Education; 1955-56 to 1964-65 actual and 1965-66 to 1974-75 projected.

APPENDIX C

Estimated Requirements for Scientists and Engineers for Teaching in Universities and Colleges

The substantial rise in requirements for teaching staff in universities and colleges over the next decade is directly related to the expected rise in enrollments (both undergraduate and graduate) and the subsequent increase in earned degrees granted. Information from the NSF survey of universities and colleges on the number of staff (full-time, part-time, and graduate students) employed in teaching (ı a full-time-equivalent basis and the expected trend in bachelor's, master's and doctoral degrees granted provided the basis for estimating requirements for scientists and engineers in teaching.

A U.S. Office of Education study[5] provided a basis for allocating science and engineering teaching staff separately to graduate and undergraduate instruction by field. For all fields of science combined, approximately 75 percent of the total FTE teaching staff was assigned to undergraduate instruction on this basis.

Next, the ratios of science bachelor's and advanced degrees to the undergraduate and graduate FTE teaching staff respectively were established. The U.S. Office of Education and Commission on Human Resources and Advanced Education earned degree series provided the numerators and the NSF university survey provided the denominators (after allocation by level and field). Since the award of the baccalaureate represents the culmination of teaching loads generally spread over four undergraduate years, an average 2-year lag in the relationship between baccalaureates and teaching staff was provided. Thus, estimated bachelor's degrees for academic year 1966-67 were related to undergraduate teaching staff of 1965. At the graduate level, there seems less reason for such lag, and the number of master's and doctor's degrees for 1964-65 was related to graduate teaching staff of 1965. These 1965 ratios were assumed to continue through 1975, as follows:

	Baccalaureates per FTE teacher	*Doctorates and master's per FTE teacher*
Physical sciences	1.607	2.526
Engineering	3.135	3.923
Life sciences	3.135	.694
Social sciences and psychology	3.994	2.744

The wide differences among these ratios are caused by several factors. Among them are differences in the extent of "service courses" provided by one department for the benefit of student majors in other departments; the greater incidence of small classes, particularly in laboratory sciences; and the average established course requirements to attain majors in different fields. In the case of the life sciences, which include professional health fields such as medicine, dentistry, pharmacy, etc., the absence of professional health degrees (M.D., D.D.S., D.V.M., etc.) in the numerator of the ratio (degrees awarded) produces a substantially lower ratio than for the other fields. For this study the professional health degrees were included with undergraduate degrees.

The ratios were than applied to the projections of degrees (appendix B) through 1975 to derive FTE teaching requirements. The number of full-time-equivalent scientists and engineers engaged in teaching in universities and colleges was about 118,000 in 1965. On the basis of the projected rise in degrees to be granted, this number is expected

[5] U.S. Office of Education, *Teaching Faculty in Universities and Four-Year Colleges, Spring 1963*, OE 53022. Washington, D. C. 20402: Supt. of Documents, U.S. Government Printing Office, 1966.

TABLE C-1. ESTIMATED REQUIREMENTS FOR FULL-TIME-EQUIVALENT TEACHING STAFF [a] IN SCIENCE AND ENGINEERING IN UNIVERSITIES AND COLLEGES, [b] 1964-65 TO 1974-75

(In thousands)

Academic year	Total	Physical scientists [c]	Engineers	Life scientists [d]	Social scientists and psychologists
1964-65	117.7	33.4	15.5	35.4	33.4
1965-66	138.3	40.7	17.6	40.1	39.9
1966-67	153.1	46.4	18.8	43.2	44.7
1967-68	156.4	48.1	18.5	43.5	46.3
1968-69	163.8	50.8	18.3	45.5	49.2
1969-70	177.1	55.2	19.4	49.9	52.6
1970-71	188.7	59.9	20.0	52.2	56.6
1971-72	201.5	65.0	20.7	54.8	61.1
1972-73	213.4	70.2	21.5	56.1	65.5
1973-74	225.5	75.4	22.2	58.7	69.2
1974-75	240.8	80.9	22.8	63.4	73.7

[a] Includes full-time and part-time staff and employed graduate students.
[b] Excludes Federal Contract Research Centers administered by these institutions.
[c] Includes mathematicians.
[d] Includes medical scientists.

Note: Detail may not add to totals because of rounding.

to rise to nearly 241,000 by 1975—an increase of 105 percent. The number of FTE staff required each year is shown in table C-1.

Though data are not available on the full costs of instruction in science and engineering fields, data on a substantial part of these expenditures are available from the 1965 NSF survey of universites and colleges. These institutions reported total current expenditures of $1.6 billion in 1964 for instructional and departmental research and estimated that indirect costs (overhead) allocable to these items were 32 percent of the base expenditures. These expenditures for instruction and departmental research include the salaries of department heads, faculty members, secretaries, and technicians; office expense and equipment; laboratory expense and equipment; and other expenses. Included are all expenditures incurred for instructional programs in science and engineering subjects for students pursuing degree-credit courses of study that lead generally to a certificate or degree.

These expenditure levels related to instruction and departmental research may be projected to increase to 1975 at the same rate as indicated by the growth in FTE staff engaged in teaching—105 percent. On this basis, the expenditures for instruction and departmental research will amount to $3.2 billion in 1975, assuming no change in the ratio of expenditures to staff in teaching. If a modest increase averaging only 2 percent per year in this ratio is assumed through the decade, 1975 expenditures for these items will total about $3.8 billion. An allowance of 32 percent in addition for indirect costs would raise the figure to $5 billion.

These expenditures do not include costs relating to such items as fellowships or to capital costs of facilities.

Estimated Requirements for Scientists and Engineers for Research in Universities and Colleges

Projections of requirements for scientists and engineers to perform research activities in universities and colleges depend upon a variety of assumptions, and can be made in several ways. Small changes in assumptions sometimes can lead to substantial differences in the projections. The selection of the most appropriate assumptions depends necessarily upon the estimator's judgment.

The use of funding levels for projecting research staff requirements was considered and rejected. Not only do such methods require assumptions as to the level of funding but they also present further complications with respect to the general price and specific research price levels. A projection method independent of funding was sought.

The 1965 NSF survey (described in appendix A) collected information on FTE staff engaged in research as well as in teaching. Research staff amounted to 29 percent of the total FTE scientists and engineers in the universities and colleges and was a little less than one-half (47 percent) as large as the number engaged in teaching.

In the absence of a more satisfactory basis for projecting research staff requirements, the 1965 ratios of research staff to teaching staff by field was extrapolated to 1975 according to the projected teacher requirements derived in appendix C. Thus, this method maintains the balance between teach-

TABLE D-1. ESTIMATED REQUIREMENTS FOR FULL-TIME-EQUIVALENT RESEARCH STAFF [a] IN SCIENCE AND ENGINEERING IN UNIVERSITIES AND COLLEGES, [b] 1964–65 TO 1974–75

(In thousands)

Academic year	Total	Physical scientists [c]	Engineers	Life scientists [d]	Social scientists and psychologists
1964–65	54.9	11.9	7.7	29.7	5.6
1965–66	63.7	14.5	8.7	33.7	6.7
1966–67	69.9	16.5	9.3	36.6	7.5
1967–68	71.1	17.1	9.2	37.0	7.8
1968–69	74.3	18.1	9.1	38.9	8.3
1969–70	80.8	19.7	9.7	42.7	8.8
1970–71	85.4	21.3	10.0	44.7	9.5
1971–72	91.3	23.1	10.3	47.6	10.2
1972–73	95.2	25.0	10.7	48.5	11.0
1973–74	100.6	26.9	11.0	51.1	11.6
1974–75	106.1	28.8	11.3	53.5	12.4

[a] Includes full-time and part-time staff and employed graduate students.
[b] Excludes Federal Contract Research Centers administered by these institutions.
[c] Includes mathematicians.
[d] Includes medical scientists.

Note: Detail may not add to totals because of rounding.

ing and research requirements by field found in the 1965 survey. On the FTE basis, research staff would accordingly increase from 55,000 in 1965 to an estimated 106,000 in the academic year 1974-75. The number estimated for each year of the period 1965-75 is shown in table D-1.

While the projection of research staff requirements upon the basis of assumed funding levels was discarded as a method, table D-2 provides some data on the relationship between staff requirements and funding levels under different assumptions of research volume. It also permits some evaluation of the projected 106,000 research staff requirement already derived.

Throughout the table an increase in academic research expenditures per research scientist averaging 3.5 percent per year between 1965 and 1975 is assumed, exclusive of price changes. This is somewhat less than the 5 to 10 percent increase of recent years, but it may be justified on the basis of a lower rate in academic salary increases and in the availability of research funds. In dollar terms, the research funding-staff ratio in 1965 was about $34,000 and under the stated assumptions would be $46,000 in 1975.

The 106,000 research staff requirement previously derived falls about midway between the estimate c of 98,000 and estimate f of 114,000. In terms of these projections, the 106,000 research staff implies an academic research funding level at about $4.9 billion per year by 1975.

TABLE D-2. ESTIMATED EXPENDITURES AND MANPOWER FOR RESEARCH AND DEVELOPMENT IN UNIVERSITIES AND COLLEGES,[a] SELECTED YEARS 1953-54 TO 1974-75

(Dollar amounts in millions)

Academic year	Expenditures for research and development				FTE scientists and engineers in R&D
	U.S. total	Federal total	Universities and colleges		
			Total	Federal	
1953-54 [b]	$ 5,730	$ 3,120	$ 380	$ 170	25,000
1960-61 [b]	14,500	9,215	970	500	42,000
1964-65 [b]	20,470	13,070	1,870	1,100	55,000
1974-75 (alternatives):					
a	30,000	19,500	2,850	1,710	61,900
b	30,000	19,500	3,600	2,340	78,700
c	30,000	19,500	4,500	2,925	98,200
d	35,000	24,500	3,325	2,160	72,500
e	35,000	24,500	4,200	2,730	91,700
f	35,000	24,500	5,250	3,413	114,500

	Assumptions for alternative R&D levels, 1974-75					
	U.S. total			Universities and colleges, percent—		
	Amount	Percent				
		Of GNP	Federally financed	Of total U.S.	Federally financed	Increase over 1965
a	$30,000	3.0	65	9.5	60	52
b	30,000	3.0	65	12.0	65	93
c	30,000	3.0	65	15.0	65	141
d	35,000	3.5	70	9.5	65	78
e	35,000	3.5	70	12.0	65	125
f	35,000	3.5	70	15.0	65	181

[a] Excludes Federal Contract Research Centers administered by these institutions.
[b] Based on surveys made by NSF (see appendix A).

Note: All assumptions include provision that GNP in 1975 will be $1,000 billion in constant (1964) dollars, that the percentage increase in research and development in universities and colleges will be accompanied by a proportionate rise in scientists and engineers, and that cost per man ratio will rise by about 35 percent by 1975.

APPENDIX E

Summary of Requirements for Science and Engineering Staff for Teaching, Research, and Other Activities in Universities and Colleges

The estimated requirements for science and engineering staff for teaching and for research activities for the next decade have been set forth in appendices C and D. Requirements for staff in other activities, such as administrative, managerial, and service activities, have also been estimated by field. This last component of full-time-equivalent staff is projected to increase to 1975 in the same ratio to teaching and research staff as existed in the base period (1965 NSF survey), approximately 12 percent for all fields combined, though the ratio varies widely by field.

A summary of the requirements for teaching, research, and other activities is shown in table E-1. In full-time-equivalent numbers, requirements are expected to rise from 193,000 in

TABLE E-1. ESTIMATED REQUIREMENTS FOR SCIENCE AND ENGINEERING STAFF FOR TEACHING, RESEARCH, AND OTHER ACTIVITIES IN UNIVERSITIES AND COLLEGES,[a] 1964-65 TO 1974-75

(In thousands)

Academic year	FTE staff[b] engaged in—			FTE total, all activities	Number employed[c]
	Teaching	Research	Other activities		
1964–65	117.7	54.9	20.0	192.6	189.6
1965–66	138.3	63.7	22.8	224.8	220.7
1966–67	153.1	69.9	24.6	247.6	242.5
1967–68	156.4	71.1	24.7	252.2	246.4
1968–69	163.8	74.3	25.6	263.7	257.4
1969–70	177.1	80.8	27.9	285.9	279.1
1970–71	188.7	85.4	29.3	303.4	295.7
1971–72	201.5	91.3	30.7	323.9	315.0
1972–73	213.4	95.2	31.5	340.1	330.1
1973–74	225.5	100.6	32.8	358.9	347.7
1974–75	240.8	106.1	34.3	381.2	368.8

[a] Excludes Federal Contract Research Centers administered by these institutions.
[b] Full-time and part-time staff and employed graduate students.
[c] "Head count" of full-time and part-time staff only; does not include employed graduate students.
Note: Detail may not add to totals because of rounding.

1964-65 to 381,000 in 1974-75. These FTE numbers include full-time and part-time staff and employed graduate students, with the latter estimated at 28,600 in 1964-65 and 56,400 in 1974-75. Next, the FTE numbers are translated into the numbers of individuals employed. The ratio of full-time and part-time staff combined (excluding employed graduate students) to total FTE staff, shown in the 1965 NSF survey, provides a basis for estimating requirements of individuals up to 1975. This ratio was calculated separately for medical scientists and for all other scientists and engineers, since separate calculations were required on staff with doctor's degrees for these groups. For the medical scientists group, because few graduate students are included in the FTE count, the ratio of full-time and part-time staff combined to total FTE staff was 119.9. The comparable ratio for all other scientists and engineers combined was 93.0, where many employed graduate students are included in the FTE count. This "head count" number of staff members is estimated to increase from 189,600 in 1964-65 to 368,800 in 1974-75. The annual increment of staff required over the decade is uneven, since the base requirements for teaching staff are estimated on the basis of degrees granted, which increase at an uneven rate through the decade.

APPENDIX F

Replacement Demand for Science and Engineering Staff in Universities and Colleges

Replacement demand for university and college staff takes account of death, retirement, and loss to other employment and represents additional numbers who must be recruited to maintain the academic staff.

The death and retirement rate has in several studies been assumed to be on the order of slightly under 2 percent per year. The 1964 Commission on Plans and Objectives of the American Council on Education (Allan M. Cartter) found a rate of 1.8 percent. Bolt, Koltun, and Levine in "Doctoral Feedback into Higher Education" found a rate of 1.6 percent. General labor force and working life tables show less than 2 percent for all working males. Scientists and engineers and the general college-educated population have lower median ages, due to a smaller proportion in older age groups, and have a higher socioeconomic status. Furthermore, the new staff recruits will be largely drawn from the younger Ph.D.'s, which will tend to lower median ages. Therefore, the death and retirement rate may be lower than the general male rate, even though faculty careers often start at an older age than for many other occupations.

There is a wide range in estimates made for attrition to other employment for university and college staff, and most of these estimates lack a solid base. Berelson, Maul, and Cartter have estimated from 2 to 4 percent for this factor. However, it would appear that these estimates are mainly based on losses from current staff without balancing additions from nonacademic employment. It would seem that losses of younger personnel should be viewed against gains of older personnel in order to obtain a true net attrition to university and college employment. Two analyses were made from data collected in connection with the National Register of Scientific and Technical Personnel.[6] A cohort of 34,870 doctorate scientists reporting in the 1960, 1962, and 1964 registers showed employment in educational institutions as: 1960, 16,071; 1962, 16,101; and 1964, 16,962. A cohort of 45,165 doctorates reporting in both 1960 and 1962 showed employment in educational institutions as 20,683 in 1960 and 20,718 in 1962. This small amount of evidence indicates that the recent net loss to other employment from educational institutions is negligible.

For this analysis, a replacement rate of 2 percent per year was applied to the total estimate of requirements (in terms of full-time and part-time employed) to represent additional recruits for replacement of deaths, retirements, and net loss to non-higher education employment. The resulting replacement requirement amounted to nearly 4,000 in 1965 and was estimated at more than 7,000 for 1975 for an average of 5,600 per year for the decade. In terms of doctorate requirements, this component implies a further need averaging nearly 3,000 per year.

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6 Published in U.S. House of Representatives, Select Committee on Government Research, *Impact of Federal Research and Development Programs,* Study No. VI, 88th Cong., 2nd sess., pp. 74–75. Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office, 1964.

APPENDIX G

Summary of Annual Doctorate Requirements and Available Doctorate Supply for Science and Engineering Staff in Universities and Colleges

The accompanying table G-1 summarizes the annual additional requirements for full- and part-time science and engineering staff (excluding graduate students) for the universities and colleges in terms of expansion and replacement needs. It shows the number of doctorates (Ph.D., Sc.D., etc.) required to maintain the 1965 staff ratio. This ratio, as mentioned in the section on supply, was calculated separately for medical scientists and for all other fields of science and engineering combined. Thus, the doctorate requirements were estimated at 25 percent of the annual number of medical scientists needed (on a "head-count" basis) and 50 percent of the annual number needed in all other fields combined. The table also shows the 50 percent of new science doctorates assumed to be available for academic posts in the year after receiving the award.

In the first two years of the decade, 1965 and 1966, the supply is exceeded considerably by requirements; however, in five years of the decade supply will be somewhat greater than the requirements. In fact, except for the first two years, the total supply for the decade is approximately equal to total requirements, although the situation displays great variation in individual years. However, the table shows a mathematical computation based upon certain benchmark data, assumptions, and previous calculations; one would not expect such great variations in the actual recruitment situation in which universities and colleges find themselves. Future needs will be anticipated, and staff will be hired as the opportunity permits with a more orderly adjustment of the academic labor market probably resulting.

TABLE G–1. SUMMARY OF SCIENCE AND ENGINEERING STAFF REQUIREMENTS FOR UNIVERSITIES AND COLLEGES [a] AND AVAILABLE DOCTORATE SUPPLY, 1965–66 TO 1974–75

(In thousands)

Academic year	Additional annual staff requirements [b] for—			Additional doctorate requirements [e]	New doctorates available [f]
	Expansion [c]	Replacement [d]	Total		
1965–66	32	4	35	16	6
1966–67	23	4	26	12	6
1967–68	4	5	9	5	7
1968–69	11	5	15	7	8
1969–70	22	6	27	12	8
1970–71	17	6	22	10	9
1971–72	20	6	25	12	10
1972–73	16	6	21	10	11
1973–74	18	7	24	12	12
1974–75	22	7	28	13	14

[a] Excludes Federal Contract Research Centers administered by these institutions.
[b] Including full-time and part-time staff, but excluding graduate students.
[c] See appendix E for requirements by activity.
[d] Attrition taken as 2 percent annually. See appendix F.
[e] Included in total; estimated at 25 percent of additional requirements for medical scientists and 50 percent for all other science fields combined. Includes Ph.D., Sc.D., and similar degrees; excludes professional degrees such as M.D. and D.D.S.
[f] Calculated at 50 percent of doctorates awarded in previous academic year; see appendix B for estimated output of doctorates.

Note: Detail may not add to totals because of rounding.

APPENDIX H

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